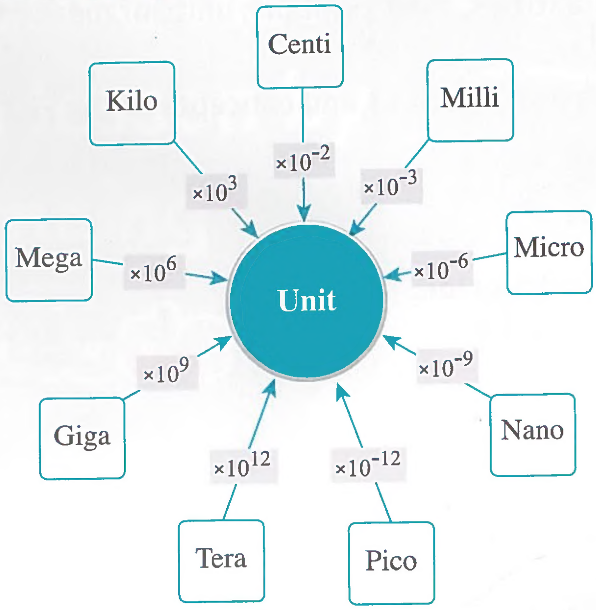
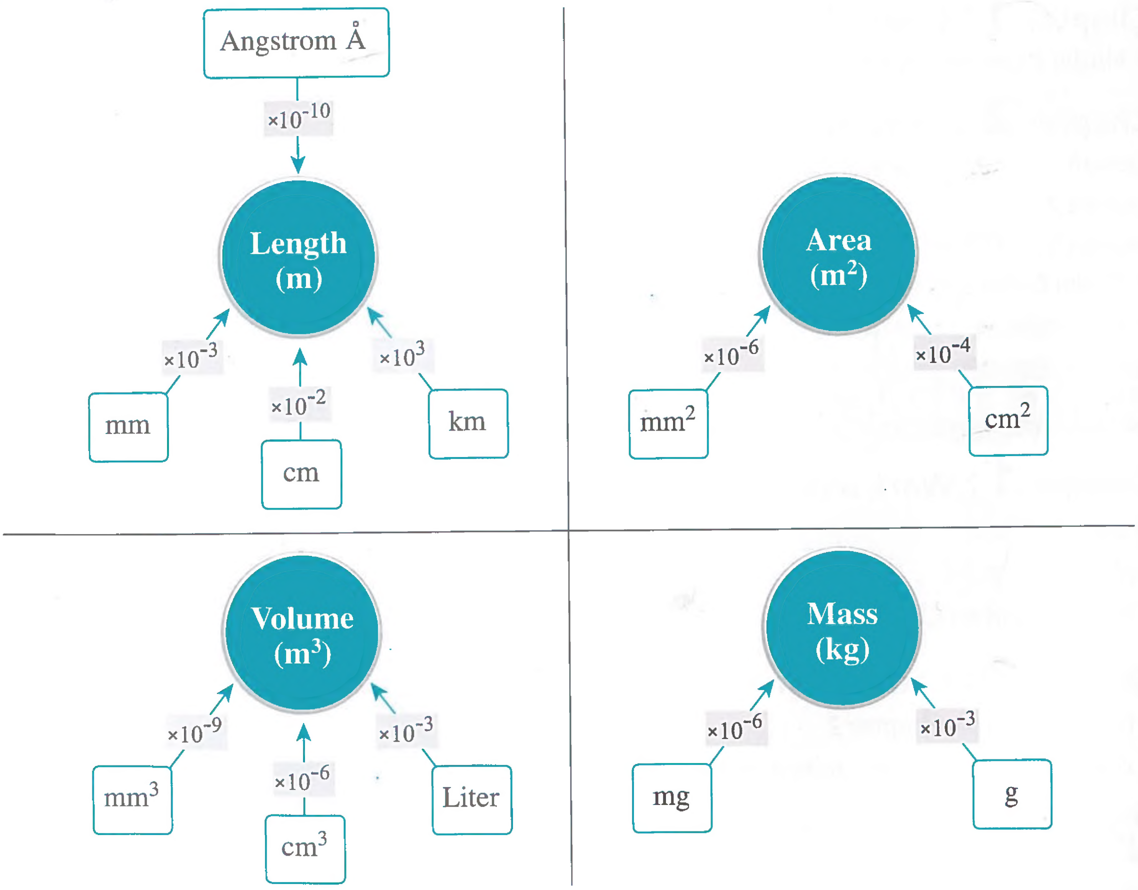
CONTENTS

Important physical and mathematical basics :

1 Some units conversion :



2 Conversions of some specific units :



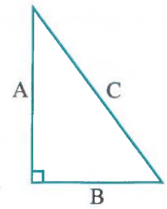
3 Pythagoras theorem :

In the right triangle the square of the hypotenuse is equal to the sum of the squares of the other two sides.

i.e. $C^2 = A^2 + B^2$

$\therefore C = \sqrt{A^2 + B^2}$

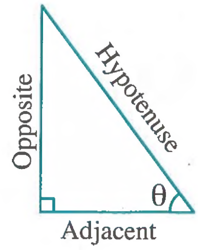
Where : C is the hypotenuse and A, B are the other two sides.



4 Trigonometrical relations :

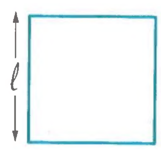
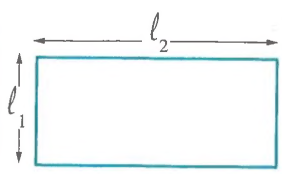
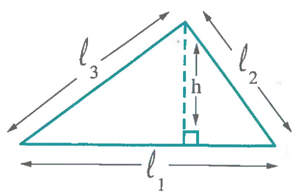
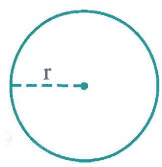
In the right triangle :

$\sin\theta = \dfrac{\text{Opposite}}{\text{Hypotenuse}}$, $\cos\theta = \dfrac{\text{Adjacent}}{\text{Hypotenuse}}$, $\tan\theta = \dfrac{\text{Opposite}}{\text{Adjacent}}$

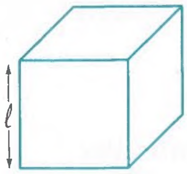
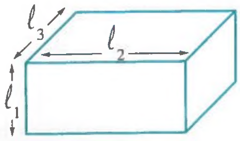
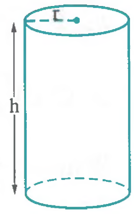


5 Perimeters, areas and volumes of some geometrical figures :

A. Plane geometrical figures :

Geometrical figure	Square	Rectangle	Triangle	Circle
Figure shape				
Perimeter	4ℓ	$2(\ell_1 + \ell_2)$	$\ell_1 + \ell_2 + \ell_3$	$2\pi r$
Area	ℓ^2	$\ell_1 \times \ell_2$	$\frac{1}{2}\ell_1 \times h$	πr^2

B. Solid geometrical figures :

Geometrical figure	Cube	Cuboid	Sphere	Cylinder
Figure shape				
Volume	ℓ^3	$\ell_1 \times \ell_2 \times \ell_3$	$\frac{4}{3}\pi r^3$	$\pi r^2 \times h$

6 Graphical relations between two variables :

- The graphical relation between two quantities on the x and y axes may be as the following :

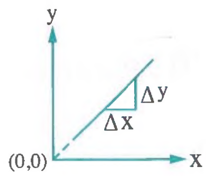
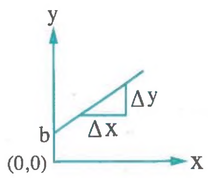
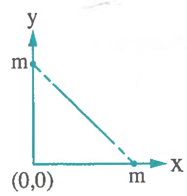
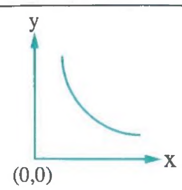
Relation	Graph
$y = mx + b$ • At : $b = 0$ - The relation is a straight line passing by the origin (0,0). - Slope $= m = \frac{\Delta y}{\Delta x}$	
• At : $b \neq 0$ - The relation is a straight line intersecting y-axis at point (0 , b). - Slope $= m = \frac{\Delta y}{\Delta x}$	
$y = m - x$ • Sum of the two quantities at any point = constant - At : $x = 0$, y = constant = m - At : $y = 0$, x = constant = m - Slope is negative value.	
$y = \frac{m}{x}$ • Product of the two quantities at any point = constant	

Table of physical quantities, their symbols, units of measurement and dimensional formulae

Physical quantity	Symbol	Unit of measurement		Dimensional formula
Length	ℓ	meter	m	L
Distance	s	meter	m	L
Displacement	d	meter	m	L
Radius	r	meter	m	L
Mass	m	kilogram	kg	M
Time	t	second	s	T
Velocity	v	meter/second	m/s	$L\,T^{-1}$
Acceleration	a	meter/second^2	m/s^2	$L\,T^{-2}$
Acceleration due to gravity	g	meter/second^2	m/s^2	$L\,T^{-2}$
Momentum	p	kg.meter/s	kg.m/s	$ML\,T^{-1}$
Force	F	kg.meter/s^2 **Or** Newton	kg.m/s^2 **Or** N	$ML\,T^{-2}$
Weight	w	kg.meter/s^2 **Or** Newton	kg.m/s^2 **Or** N	$ML\,T^{-2}$
Universal gravitational constant	G	Newton.meter^2/kg^2 **Or** meter^3/kg.s^2	N.m^2/kg^2 **Or** m^3/kg.s^2	$M^{-1}L^3T^{-2}$
Work	W	kg.meter^2/s^2 **Or** Newton.m **Or** Joule	kg.m^2/s^2 **Or** N.m **Or** J	ML^2T^{-2}
Potential energy	PE			
Kinetic energy	KE			

Review of the important relations and concepts of the First Term

Accumulative knowledge from the First Term

In this section we will revise some important concepts and relations that we have studied in the First Term.

1 Physical equation :

This mathematical formula is called physical equation it shows the definition of acceleration.

$$\vec{a} = \frac{\Delta \vec{v}}{\Delta t}$$

The arrow in the symbol of acceleration ($\vec{a}$) indicates that acceleration has direction which means it's a vector quantity.

Velocity ($\vec{v}$) is a vector quantity and a derived quantity which can be defined by : $\vec{v} = \frac{\vec{d}}{t}$

Its unit is m/s^2.

From the equation we can notice that acceleration is defined in terms of other physical quantities which are velocity and time. The unit of measuring acceleration is derived from the equation which is m/s^2.

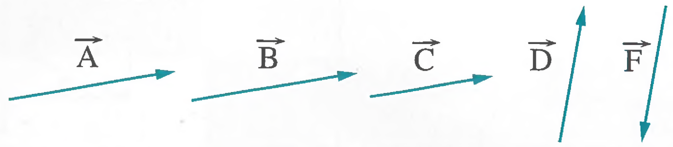
Time is a fundamental physical quantity because it is not defined in terms of other physical quantities. It is scalar because it has no direction. Its unit is second.

- To add or subtract two or more physical quantities they must be of the **same type** or has the **same measuring unit** and the resulted quantity will be of the same type.
- We can multiply or divide physical quantities that are not of the same type (have different measuring units) and that results a **new physical quantity**.

2 Vectors :

The physical quantity that has magnitude and direction is called **vector**.

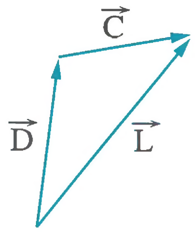
$\vec{A}$, $\vec{B}$, $\vec{C}$, $\vec{D}$ and $\vec{F}$ are vectors.



	Because they :
$\vec{A} = \vec{B}$	have the same magnitude and the same direction even if they have different starting points.
$\vec{A} \neq \vec{C}$	have different magnitudes and the same direction.
$\vec{A} \neq \vec{D}$	have different directions and the same magnitude.
$\vec{D} = -\vec{F}$	have the same magnitudes and they are in opposite directions.

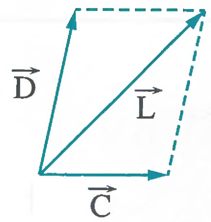
3 Adding two vectors :

(a) Joining the tail of $\vec{C}$ with the arrow of $\vec{D}$ or vice versa.



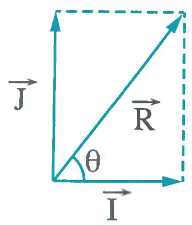
Or

(b) Joining their two tails.



$\vec{C} + \vec{D} = \vec{L}$

4 Adding two perpendicular vectors :

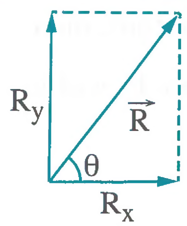


$\vec{I} + \vec{J} = \vec{R}$ $\qquad$ $I^2 + J^2 = R^2$

$R = \sqrt{I^2 + J^2}$

$\tan\theta = \frac{J}{I}$

5 Resolving a vector $\vec{R}$ into two perpendicular components :

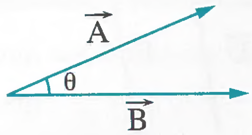


$\cos\theta = \frac{R_x}{R}$ $\qquad$ $\sin\theta = \frac{R_y}{R}$

$R_x = R\cos\theta$ $\qquad$ $R_y = R\sin\theta$

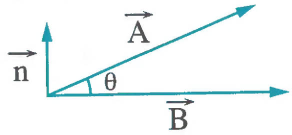
6 Product of two vectors :

Scalar or dot product



$$\vec{A} \cdot \vec{B} = AB \cos \theta$$

Vector or cross product



$$\vec{A} \wedge \vec{B} = AB \sin \theta \, \vec{n}$$

7 Important relations :

Velocity

$$\vec{v} = \frac{\Delta \vec{d}}{\Delta t}$$

Acceleration

$$\vec{a} = \frac{\Delta \vec{v}}{\Delta t}$$

8 Equations of motion :

1st equation

$$\vec{v}_f = \vec{v}_i + \vec{a}\, t$$

2nd equation

$$\vec{d} = \vec{v}_i t + \frac{1}{2} \vec{a}\, t^2$$

3rd equation

$$2\, ad = v_f^2 - v_i^2$$

9 Newton's first law :

If the net force $\Sigma\vec{F}$ that acts on an object equals zero $(\Sigma\vec{F} = 0)$, the object will keep its state;

- If the object is at rest $\Longrightarrow$ it will stay at rest.
- If the object is moving $\Longrightarrow$ it will keep moving at constant velocity.

10 Newton's third law :

For every action force there is an equal and opposite reaction.

- If $\vec{F}_1$ is applied, $\vec{F}_2$ will be initiated with the same magnitude and in opposite direction so :

$$\vec{F}_1 = -\vec{F}_2$$

UNIT 2

Linear Motion

Unit objectives

By the end of this unit, the student will be able to :

Chapter 3 :

- Define the concept of momentum.
- Apply the relation between force, mass and acceleration.

Chapter 3

Force and Motion.

(Momentum - Newton's Second Law)

▶ Model Exam on Chapter 3.

Chapter 3

Force and Motion (Momentum - Newton's Second Law)

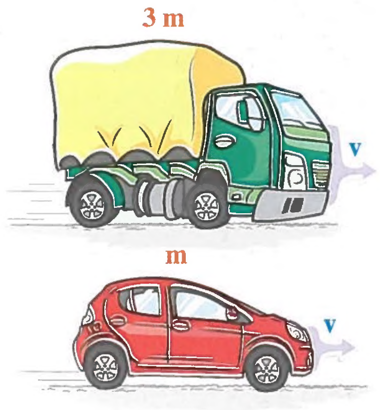
- We studied Newton's first and third laws in the **First Term** and now we will study the concept of momentum and Newton's second law :

Momentum :

- You notice that stopping the objects which are moving under the effect of inertia depends on both :

Mass m

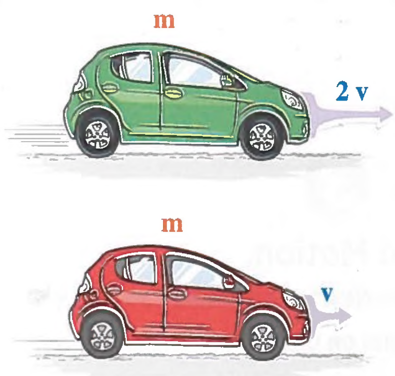
As the mass of the body increases its inertia increases



So, it is difficult to stop a truck, while it is easy to stop a car if they have the same velocity.

Velocity v

As the velocity of the body increases its inertia increases



So, it is difficult to stop a car that is moving with high velocity, while it is easy to stop it when it is moving with low velocity.

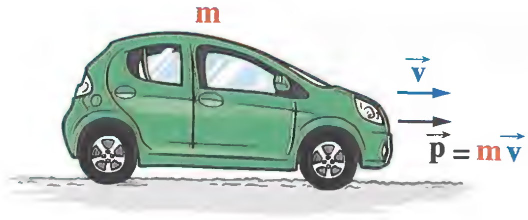
⊙ The velocity (v) and the mass (m) are related to a physical quantity known as **momentum (p)** which is given by the relation : $p = mv$

The measuring unit of **Momentum** is **kg.m/s** and its dimensional formula is **MLT^{-1}**

Notes :

1. Momentum is a vector quantity,

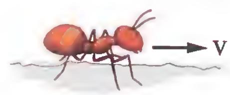
because it is the product of a scalar quantity (mass) and a vector quantity (velocity) and its direction is in the same direction of the velocity.



2. According to the relation (p = mv), then the :

Momentum

For a static body **equals zero** regardless the increase of its mass.	For a moving body **doesn't equal zero** regardless the decrease of its mass.



Because the velocity of the static body equals zero.
$\therefore p = m \times 0 = 0$

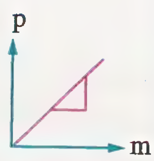
Because the velocity of the moving body doesn't equal zero, so its momentum doesn't equal zero.

The factors that affect momentum :

1 Mass :

The momentum is directly proportional to the mass of the object at constant velocity.

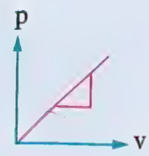
Slope $= \frac{\Delta p}{\Delta m} = v$



2 Velocity :

The momentum is directly proportional to the velocity of the object at constant mass.

Slope $= \frac{\Delta p}{\Delta v} = m$



$p = mv$

Example 1

Calculate the momentum of a body of mass 5 kg that is moving with a velocity of 2 m/s.

Solution

$m = 5\ kg$ | $v = 2\ m/s$ | $p = ?$

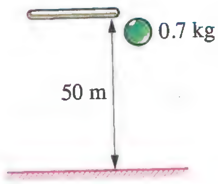
$p = mv = 5 \times 2 = 10\ kg.m/s$

Example 2

A ball of mass 0.7 kg falls freely from a height of 50 m, calculate the momentum of the ball at the instant of hitting the ground neglecting the resistance of air. (knowing that : $g = 10\ m/s^2$)

Solution

$m = 0.7\ kg$ | $v_i = 0$ | $d = 50\ m$ | $g = 10\ m/s^2$ | $p = ?$



The velocity of the ball at the instant of hitting the ground :

$v_f^2 = v_i^2 + 2\,g\,d$

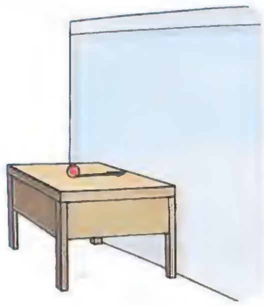
$v_f = \sqrt{0 + (2 \times 10 \times 50)} = 10\sqrt{10}\ m/s$

The momentum of the ball at the instant of hitting the ground :

$p = mv_f = 0.7 \times 10\sqrt{10} = 7\sqrt{10}\ kg.m/s$

Example 3

The opposite figure represents a ball of mass 200 g that is placed on a horizontal table. If the ball is pushed to move horizontally towards a vertical wall and collides with it at a velocity of 0.7 m/s then it rebounds with a velocity of 0.4 m/s. Find the change in the momentum of the ball due to the collision neglecting the resistance of air.



Solution

$m = 200\ g$ | $v_1 = 0.7\ m/s$ | $v_2 = -0.4\ m/s$ | $\Delta p = ?$

Clue

- *Since the ball moved in two opposite directions (before and after the collision), so if we assume that the direction of motion before the collision is the positive direction of motion then the direction of motion after the collision is the negative direction of motion.*
- *The change in the momentum is given by the relation :*
  $\Delta p = p_{after\ collision} - p_{before\ collision}$

The momentum before collision :

$p_1 = mv_1 = 200 \times 10^{-3} \times 0.7 = 0.14$ kg.m/s

The momentum after collision :

$p_2 = mv_2 = 200 \times 10^{-3} \times (-0.4) = -0.08$ kg.m/s

The change in momentum due to collision :

$\Delta p = p_2 - p_1 = -0.08 - 0.14 = -0.22$ kg.m/s

1 Test yourself

Answered

Can the magnitude of the momentum of a car of mass (m) be equal to the magnitude of the momentum of a car of mass (3 m) ? **Explain your answer.**

....

....

....

Newton's second law

Newton's second law of motion :

"The resultant force affecting an object is equal to the rate of change in the object's momentum".

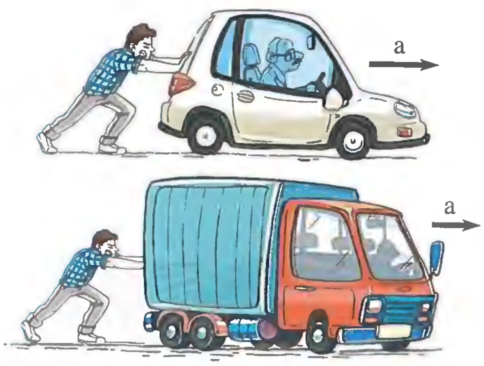
Or :

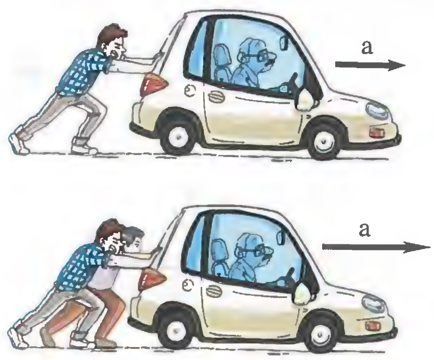
"When a resultant force affects an object, the object acquires an acceleration which is directly proportional to the resultant force and inversely proportional to the object's mass".

Explanation of Newton's second law :

When a resultant force acts on a car during an interval of time, its velocity increases and acquires an acceleration, **so if :**

Two equal forces is acting on two different masses	Two different forces is acting on two equal masses
Then	**Then**
The higher mass moves with less acceleration	The mass that is affected by a higher force moves with higher acceleration





which means that

Acceleration is inversely proportional to mass at constant force ($a \propto \frac{1}{m}$)

Acceleration is directly proportional to force at constant mass ($a \propto F$)

Deducing the mathematical formula of Newton's second law

Proof

$$F = \frac{\Delta p}{\Delta t} = \frac{\Delta mv}{\Delta t} = \frac{mv_f - mv_i}{\Delta t} = m\frac{(v_f - v_i)}{\Delta t} = m\frac{\Delta v}{\Delta t}$$

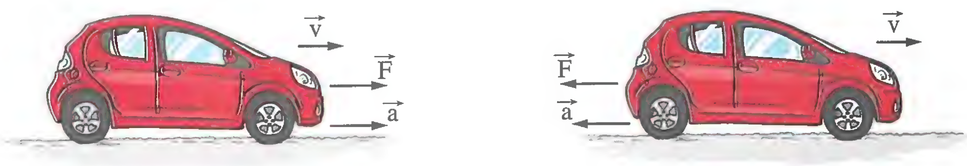
$\therefore$ $\boxed{F = ma}$ **Or** $\boxed{a = \frac{F}{m}}$

The measuring unit of **Force** is **kg.m/s^2** that is equivalent to **Newton (N)** and its dimensional formula is **$ML T^{-2}$**

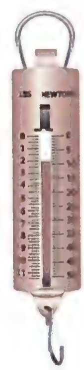
Newton :

It is the force that when acts on an object of mass 1 kg accelerates it at 1 m/s^2 in the same direction of the force.

- **The force (F) is a vector quantity,** because it is the product of a scalar quantity (mass) and a vector quantity (acceleration) and the direction of acceleration is always in the same direction of the resultant force.



- The force can be measured by the **spring balance** that is shown in the opposite figure.

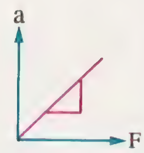


The factors that affect acceleration :

1 The resultant force :

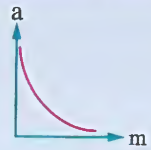
The acceleration is directly proportional to the resultant force acting on the object at constant mass.

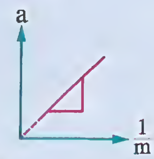
Slope $= \frac{\Delta a}{\Delta F} = \frac{1}{m}$



2 The object's mass :

The acceleration is inversely proportional to the object's mass at constant resultant force.





Slope $= \frac{\Delta a}{\Delta(\frac{1}{m})} = F$

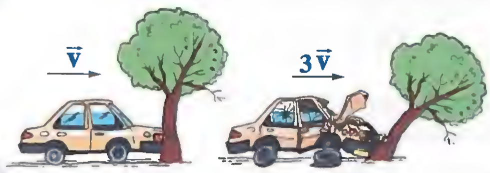
$$a = \frac{F}{m}$$

Life applications of Newton's second law :

According to Newton's second law ($F = m\frac{\Delta v}{\Delta t}$), when a moving body collides with a static body, the **force of collision (F)** :

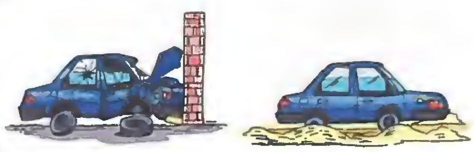
increases by increasing the mass of the moving body (m) when the other factors remain constant **for example :**
the collision of a large truck with a body is more destructive than the collision of a small car moving with the same velocity.

increases by increasing the change in the velocity of the body (Δv) when the other factors remain constant **for example :**
the collision of a car with a body is less destructive than the collision of a car that have the same mass but moving with larger velocity.



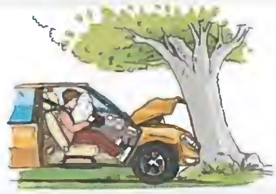
decreases by increasing the time of impact (the time interval of the change in the momentum Δt) when the other factors remain constant **for example :**

1. The collision of a car with a wall is more destructive than its collision with a haystack.



2. An egg will not break if it falls on a pillow, while it will break if it falls from a height on the ground.

3. It is preferable to use airbags in cars to protect the driver during accidents.



4. If a person falls from a height in water he will not be harmed while if he falls on the ground he will be harmed and the severity of injury increases by increasing the height of falling.

Notes :

1. If a body moves in a straight line on a horizontal surface under the effect of two forces which are a horizontal thrust force (F_{acting}) and a friction force ($F_{friction}$) between the surface and the moving body, so the resultant force (F_{moving}) that acts on the body is given by the relation : $\Sigma F = F_{moving} = F_{acting} - F_{friction}$

   The negative sign indicates that the friction force acts in opposite direction.

F_{acting}
(Thrust force of the car)

$F_{friction}$
(Friction force between the car tyres and the road)

2. If there are more than one force that act on the body, then the resultant force $\Sigma F = F_{moving} = F_1 + F_2 + F_3 + ...$, where the forces that act in opposite direction such as the friction force take negative signs.
3. If a resultant constant force (F) acts on a body, it will move with a uniform acceleration (a) and its motion will be described by the three equations of motion.

Example 1

A car of mass 1000 kg moved with a uniform acceleration from rest to acquire a velocity of 20 m/s after a time period of 5 s. Calculate the pushing force of the car. (assume that there is no friction force)

Solution

$m = 1000$ kg | $v_i = 0$ | $v_f = 20$ m/s | $t = 5$ s | $F = ?$

$$a = \frac{v_f - v_i}{t} = \frac{20 - 0}{5} = 4 \text{ m/s}^2$$

$F = ma = (1000)(4) = 4000$ N

Example 2

A force of 20 kg.m/s^2 acts on a body of mass 3 kg that is placed on a horizontal surface to move it at a uniform acceleration of 4 m/s^2. Find the frictional force between the body and the surface.

Solution

$F_{acting} = 20$ kg.m/s^2 | $m = 3$ kg | $a = 4$ m/s^2 | $F_{friction} = ?$

$F_{moving} = F_{acting} - F_{friction}$

$F_{friction} = F_{acting} - F_{moving} = F_{acting} - ma = 20 - (3 \times 4) = 8$ N

Example 3

A force of 1 N acts on a wooden cube to give it a certain acceleration. When the same force acts on another cube, it accelerates it three times the first cube. Find the ratio between the mass of the first cube and the mass of the second cube neglecting the friction forces.

Solution

$F = 1$ N | $a_2 = 3\,a_1$ | $\frac{m_1}{m_2} = ?$

$\because m = \frac{F}{a}$

$\because$ F is constant.

$\therefore \frac{m_1}{m_2} = \frac{a_2}{a_1} = \frac{3}{1}$

Example 4

A tennis ball of mass 0.06 kg is projected vertically upwards, then it is hit by a racket when it reaches its maximum height. If it leaves the racket after a time of impact of 4 ms with a velocity of 55 m/s, calculate the average acting force on the tennis ball during the time of impact.

Solution

$m = 0.06$ kg | $v_i = 0$ | $\Delta t = 4$ ms | $v_f = 55$ m/s | $F = ?$

Clue

The velocity of the ball at its maximum height equals zero, so its initial velocity when it touches the racket equals zero.

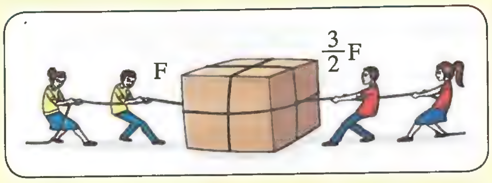
$$F = \frac{\Delta p}{\Delta t} = \frac{mv_f - mv_i}{t} = \frac{m(v_f - v_i)}{t} = \frac{0.06\,(55 - 0)}{4 \times 10^{-3}} = 825 \text{ N}$$

Test yourself

Answered

Choose :

1. Two groups of students pull a box in two opposite directions as in the opposite figure. If the friction force between the box and the surface is $\frac{F}{4}$, then the box will move ....



ⓐ to the left with constant velocity
ⓑ to the left with constant acceleration
ⓒ to the right with constant velocity
ⓓ to the right with constant acceleration

2. A man acts on a static box that is placed on a horizontal frictionless surface by a force F to reach velocity v after time t. If the man repeats the experiment with a force of 2F, then the box will reach the same velocity v after time ....

ⓐ 4 t
ⓑ 2 t
ⓒ $\frac{t}{2}$
ⓓ $\frac{t}{4}$

Practical Experiment

The relation between acceleration and force.

1. Experiment Objective :

- Deducing the relation between the acting force on a body and the resulted acceleration from this force.

2. Experiment Idea :

- Finding the acceleration (a) by which a small cart moves when it is pulled by a known force (F) resulted from a known mass (m), using the relation :

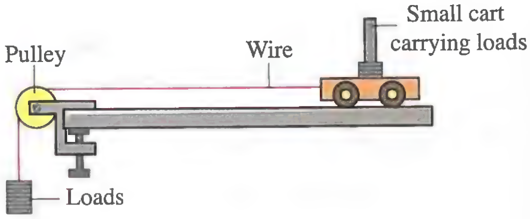
$$a = \frac{F}{m}$$

- Plotting a graph of acceleration versus force to conclude the relation between them.

3. Tools :

1. Small cart.
2. Loads of known masses.
3. Wire.
4. Pulley.
5. Stopwatch.

4. Procedure :



1. Set up the tools as shown in the figure.
2. Add loads gradually each of (5 g) till the cart starts moving slowly.
3. Hang a load of 10 g to the hook.
4. Measure the distance moved by the cart (d) and measure the time (t) taken to cover it using a stopwatch.

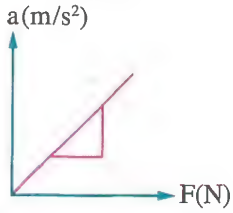
5. Repeat the previous step three times and find the average time.
6. Calculate the acting force on the cart using the relation : $F = mg$
7. Find the acceleration of the cart's motion using the relation : $a = \frac{2\,d}{t^2}$
8. Repeat the previous steps by adding a load of (10 g) to the hook each time.
9. Record your results in the table below :

Mass	Force	Time (t)	Square of time (t^2)	Displacement	Acceleration
0.01 kg	0.1 N				
0.02 kg	0.2 N				
0.03 kg	0.3 N				

10. Plot a graph between force on the horizontal axis and acceleration on the vertical axis.

5. Conclusion :

- When plotting a graph between force on the horizontal axis and acceleration on the vertical axis, we get a straight line that passes through the origin.
  The slope of the line $= \frac{\Delta a}{\Delta F} = \frac{1}{m}$



i.e. The acceleration of motion is directly proportional to the resultant force acting on the object.

Mass and Weight

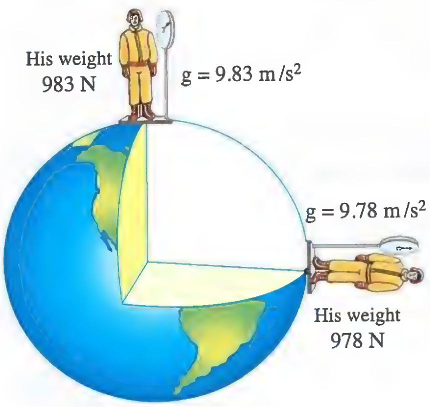
⇒ **The concept of mass (m) differs from that of weight (w) as illustrated in the table below :**

Points of comparison	Mass (m)	Weight (w)
Definition :	The resistance of an object to change its kinematic state. 	The force of gravity acting on the body. 

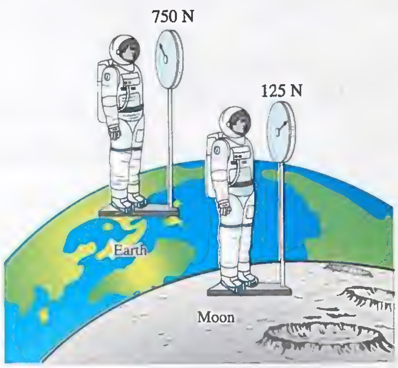
Type of physical quantity :	Fundamental scalar quantity,	Derived vector quantity, its direction is towards the Earth's center.
The mathematical relation :	$m = \frac{F}{a}$	$w = mg$
Measuring unit :	Kilogram (kg)	Newton (N)
Dimensional formula :	M	MLT^{-2}
Effect of position :	Constant everywhere.	Changes by changing the acceleration due to gravity from one position to another.

Notes :

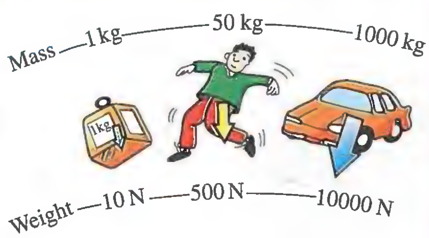
1. The weight of a body changes from one place to another on Earth.
Due to the change of the acceleration due to gravity slightly from one place to another on Earth ($w = mg$).



2. The weight of an astronaut on the Moon is different from his weight on Earth.
Due to the difference between the acceleration due to gravity on the Moon and that on Earth.



3. The body's weight on Earth is numerically greater than its mass,
because the body's weight = Its mass × The acceleration due to gravity



Example : The body's mass = 50 kg
The body's weight = 50 × 10 = 500 N

(assuming that the acceleration due to gravity on Earth = 10 m/s^2)

Example 1

Calculate the weight of a man of mass 70 kg if he was in a car moving horizontally at an acceleration of 4 m/s^2. *($g = 9.8\ m/s^2$)*

Solution

$m = 70$ kg | $a = 4\ m/s^2$ | $g = 9.8\ m/s^2$ | $w = ?$

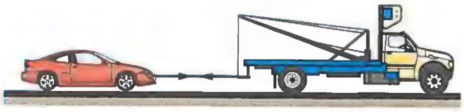
Clue

The weight of the man depends on its mass and the acceleration due to the gravity acting on him and it doesn't depend on the acceleration of the car (the acceleration of the man).

$w = mg = 70 \times 9.8 = 686$ N

Example 2

A car was pulled by a force of 3000 N to move it at an acceleration of 3 m/s^2. Find the mass and the weight of the car. (given that : $g = 9.8\ m/s^2$)



Solution

$g = 9.8\ m/s^2$ | $F = 3000$ N | $a = 3\ m/s^2$ | $m = ?$ | $w = ?$

$\because F = ma$ $\quad \therefore 3000 = m \times 3$ $\quad \therefore m = 1000$ kg

$w = mg = 1000 \times 9.8 = 9800$ N

3 Test yourself

Answered

Choose : If the reading of a balance when a student stands on it by his two feet is 500 N, then the reading will be .... when the student lifts one of his feet.

ⓐ 0 ⓑ 250 N

ⓒ 500 N ⓓ 1000 N

QUESTIONS ON

Chapter 3

Force and Motion (Momentum - Newton's Second Law)

Interactive test

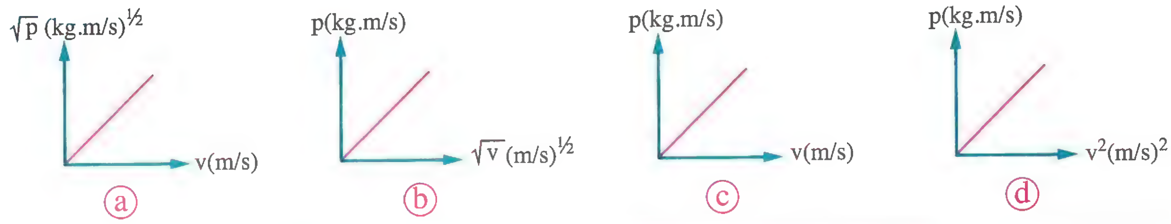
First Multiple choice questions

1 The product of the mass of a body and the rate of change of its displacement is called ....

ⓐ force ⓑ momentum ⓒ acceleration ⓓ weight

---

2 The graph .... represents the relation between the momentum and the velocity of an object.



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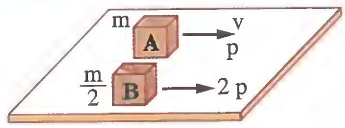
3 The opposite figure represents a body A of mass m and velocity v and momentum p, and another body B of mass $\frac{m}{2}$ and momentum 2 p so its velocity is ....



ⓐ $\frac{v}{2}$ ⓑ v

ⓒ 2 v ⓓ 4 v

---

4 When a body falls freely towards the ground its .... **(Choose two answers)**

ⓐ momentum increases ⓑ mass increases

ⓒ acceleration remains constant ⓓ velocity decreases

ⓔ weight increases

---

5 The opposite figure shows a ball of mass 0.5 kg that falls freely towards the surface of Earth, so its momentum when it reaches the Earth's surface is .... ($g = 10\ m/s^2$)

ⓐ 3 kg.m/s ⓑ 5 kg.m/s

ⓒ 6 kg.m/s ⓓ 9 kg.m/s

---

6 The mathematical relation for Newton's second law is .... **(Choose two answers)**

ⓐ $F = \frac{\Delta(mv)}{\Delta t}$ ⓑ $F = \frac{m\,\Delta v^2}{\Delta t}$

ⓒ $F = \frac{v\,\Delta m^2}{\Delta t}$ ⓓ $F = \frac{m\,\Delta p}{\Delta t}$

ⓔ $F = ma$

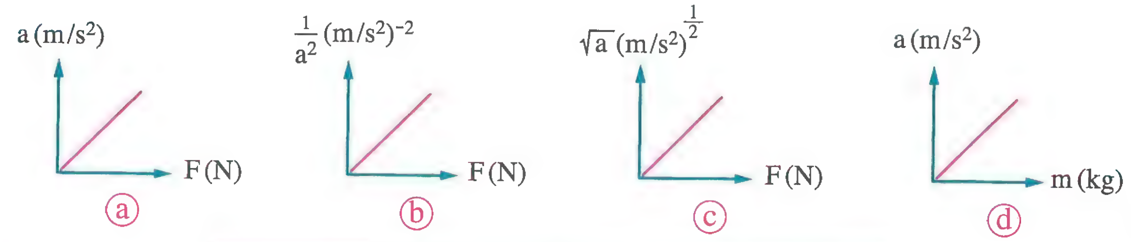
7. The ratio between the acting force on the body and the rate of change of its velocity according to Newton's second law is the ....

ⓐ momentum of the body ⓑ mass of the body
ⓒ energy of the body ⓓ acceleration of the body

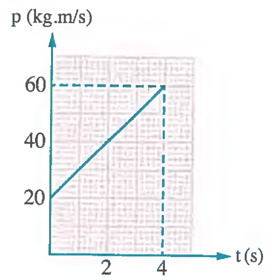
8. The unit that is equivalent to $kg.m.s^{-1}$ is .... **(Choose two answers)**

ⓐ N ⓑ N.s
ⓒ N/s ⓓ J.s
ⓔ J.s/m

9. The graph that represents Newton's second law is ....



10. The opposite graph represents the relation between the momentum and the time for a body that moves in a straight line on a horizontal frictionless surface under the effect of a constant force, then the acting force on the body equals ....



ⓐ 6 N ⓑ 10 N
ⓒ 15 N ⓓ 18 N

11. If a force of 2 N acts on an object of mass 1 kg, the object acquires ....

ⓐ velocity of 2 m/s ⓑ acceleration of 2 m/s^2
ⓒ acceleration of 1 m/s^2 ⓓ velocity of 1 m/s

12. An object of mass 10 kg is accelerating by 2 m/s^2, so the acting force on it equals ....

ⓐ 5 N ⓑ 10 N ⓒ 15 N ⓓ 20 N

13. The force that acts on an object of mass 5 kg to change its velocity from 7 m/s to 3 m/s in an interval of 2 s is ....

ⓐ 10 N ⓑ 5 N ⓒ – 2 N ⓓ – 10 N

14. If the force acting on a body is doubled while its mass is decreased to its half, then the acceleration of its motion ....

ⓐ decreases to its half ⓑ is doubled
ⓒ increases four times ⓓ decreases to its quarter

15 A vehicle of mass 500 kg and another of mass 1500 kg are moving at the same acceleration. The force acting on the heavier vehicle will be .... the force acting on the less mass vehicle.

ⓐ equal to ⓑ half ⓒ twice ⓓ three times

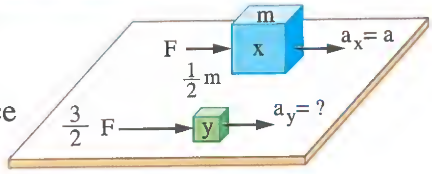
---

16 The ratio between the acceleration of a body of mass 2 kg to that of a body of 4 kg when they move under the effect of the same force is ....

ⓐ $\frac{2}{1}$ ⓑ $\frac{1}{2}$ ⓒ $\frac{4}{1}$ ⓓ $\frac{1}{4}$

---

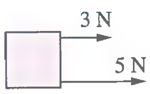
17 The opposite figure represents a body (x) of mass m that acts on it a force F to accelerate it a uniform acceleration a and another body (y) of mass $\frac{1}{2}$ m that acts on it a force of $\frac{3}{2}$ F to accelerate it a uniform acceleration of ....



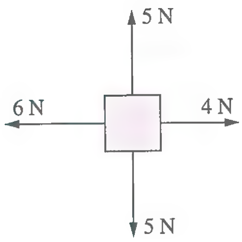
ⓐ $\frac{1}{3}$ a ⓑ $\frac{3}{2}$ a ⓒ 3 a ⓓ 6 a

---

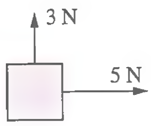
18 Two forces 3 N and 5 N act on a certain body, which of the following figures represents the least value of the acceleration by which the body will move ? .... **(Choose two answers)**



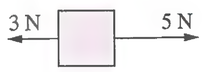
ⓐ



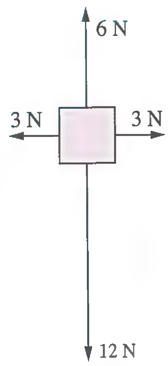
ⓑ



ⓒ



ⓓ



ⓔ

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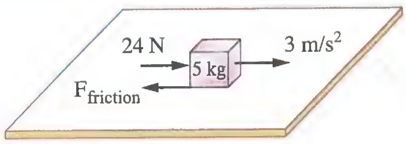
19 A horizontal force of 24 N acts on a body of mass 5 kg to move it on a horizontal surface with acceleration of 3 m/s^2, then the magnitude of the friction forces equals ....



ⓐ 6 N ⓑ 8 N ⓒ 9 N ⓓ 39 N

---

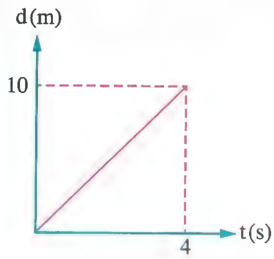
20 A wooden block of mass 2 kg was moving along a horizontal plane when affected by a force of 6 N. If the frictional force was 2 N, the acceleration of motion equals ....

ⓐ 6 m/s^2 ⓑ 2 m/s^2 ⓒ – 3 m/s^2 ⓓ – 4 m/s^2

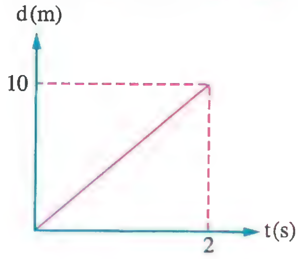
21 The weight of a body is 120 N on Earth, so its weight on the Moon = ... N
(notice that : the acceleration due to gravity on the Moon = $\frac{1}{6}$ the acceleration due to gravity on the Earth)

ⓐ 20 ⓑ 60 ⓒ 100 ⓓ 120

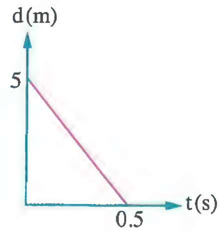
22 The next graphs represent the (displacement - time) curves for five moving bodies that have the same mass, so the two graphs that represents the two bodies of the largest magnitude of momentum are .... **(Choose two answers)**



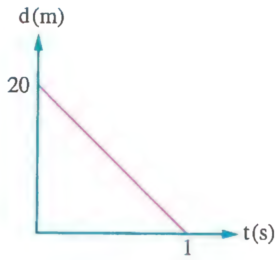
ⓐ



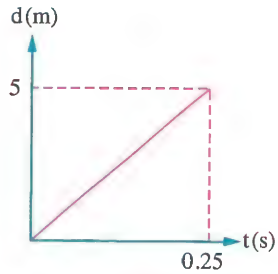
ⓑ



ⓒ



ⓓ

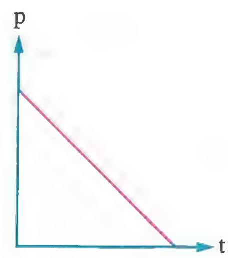


ⓔ

23 A car of mass 1000 kg started motion from rest with a uniform acceleration, so its momentum after 2 s was 4×10^3 kg.m/s, thus after 4 s from starting motion, its momentum will be .... kg.m/s.

ⓐ 8×10^3 ⓑ 16×10^3 ⓒ $4\sqrt{2} \times 10^3$ ⓓ $8\sqrt{2} \times 10^3$

24 The opposite graph represents the relation between the momentum of a body that is affected by a force F and the time, so the force that acts on the body is ....

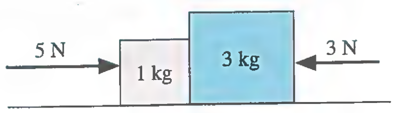


ⓐ absent
ⓑ in the same direction of motion
ⓒ in the opposite direction of motion
ⓓ perpendicular to the direction of motion

25 A car of mass 240 kg starts its motion from rest on a straight horizontal road under the effect of a force of 750 N, so its velocity reached 5 m/s after a distance of 10 m, then the friction force between the car and the surface of Earth = ...

ⓐ 150 N ⓑ 200 N ⓒ 300 N ⓓ 450 N

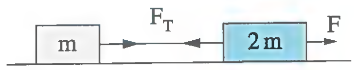
26 In the opposite figure : The net force on the bigger mass will be ....



ⓐ greater than 2 N ⓑ equal to 2 N

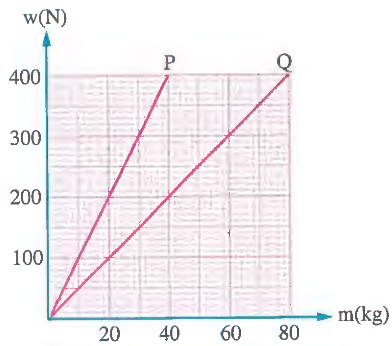
ⓒ less than 2 N ⓓ no correct answer

27 Two bodies that are connected with a rope of negligible mass are placed on a smooth surface. If an external force (F) acts as in the opposite figure to move the two bodies together by a uniform acceleration, then the tension force (F_T) in the rope equals ....



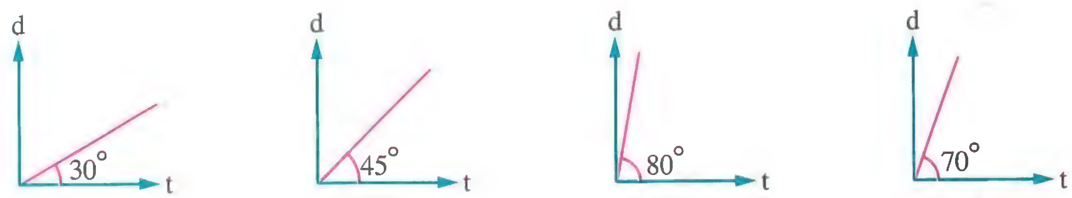
ⓐ zero ⓑ 2 F ⓒ F ⓓ $\frac{F}{3}$

28 The opposite graph represents the relation between the weight and the mass of a group of bodies when they are placed on two planets P and Q. If a body that weighs 650 N on planet P is translated to planet Q, then ....



	The mass of the body on planet Q (kg)	The weight of the body on planet Q (N)
ⓐ	130	325
ⓑ	130	1300
ⓒ	65	325
ⓓ	65	1300

29 The following graphs illustrate a group of objects that have the same mass and they are all drawn to the same scale, so the graph that expresses the object of the highest momentum is ....



ⓐ ⓑ ⓒ ⓓ

30 A boy pushes a 10 kg crate across the floor with a constant force of 10 N against a force of friction. The box accelerates at a rate of 0.1 m/s^2. What is the magnitude of the opposing frictional force ? ....

ⓐ 0 ⓑ 1 N ⓒ 5 N ⓓ 9 N

31 A jet flies horizontally where its engines produce a total of 20000 N of forward thrust. If the jet's mass is 50000 kg and it accelerates at 0.3 m/s^2, so what is the magnitude of the air resistance against which the jet flies ? ....

ⓐ 1000 N ⓑ 3000 N ⓒ 5000 N ⓓ 10000 N

32 A car with a mass of 1000 kg travels at 30 m/s. The driver applies his brakes for a uniform deceleration and comes to a complete stop in 60 m. Assuming that the forward motion is positive, what is the net force acting on the car ? ....

ⓐ 7500 N ⓑ 5000 N ⓒ – 5000 N ⓓ – 7500 N

33 A bowler applies a constant net force of 100 N on a 5 kg bowling ball over a time period of 1.5 s before he releases the ball. If the ball starts from rest, so what will be its final velocity ? ....

ⓐ 5 m/s ⓑ 10 m/s ⓒ 20 m/s ⓓ 30 m/s

34 A girl pushes a 10 kg box from rest across a horizontal floor with a force of 50 N. The force of friction opposing her is 45 N. If the box uniformly accelerates from rest to a final velocity of 2 m/s, how much time did it take to get to that velocity ? ....

ⓐ 1 s ⓑ 2 s ⓒ 3 s ⓓ 4 s

35 A rocket goes from rest to 9.6 km/s in 8 minutes. The rocket's mass is 8×10^6 kg. Assuming a constant acceleration, what is the net force acting on the rocket ? ....

ⓐ 1.6×10^5 N ⓑ 9.6×10^5 N ⓒ 9.6×10^6 N ⓓ 1.6×10^8 N

36 A 1000 kg car is initially travelling at 30 m/s. The driver applies the brakes suddenly and the friction from the road exerts 9000 N of force on the car. If the car uniformly decelerates to a complete stop, how far does the car travel during the braking process ? ....

ⓐ 2 m ⓑ 50 m ⓒ 100 m ⓓ 200 m

37 At a race, a 70 kg runner accelerates uniformly from rest to 10 m/s in 0.5 s as she moves in the positive direction. What is the net force acting upon the runner ? ....

ⓐ –7000 N ⓑ –1400 N ⓒ 0 ⓓ 1400 N

38 Rank the following scenarios from the smallest acceleration to the greatest acceleration :

I. Net force F applied to a mass M

II. Net force 2 F applied to a mass M

III. Net force F applied to a mass 2M

IV. Net force 2 F applied to a mass 2M

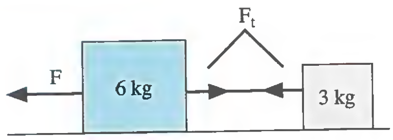
ⓐ II > I = IV > III ⓑ I > II > III > IV

ⓒ III > IV = I > II ⓓ IV > II > III > I

39 Two static objects of masses 2 kg, 18 kg are affected by two equal forces. They moved in a straight line and covered the same displacement, so the ratio between their final velocities $\frac{v_1}{v_2}$ = ...

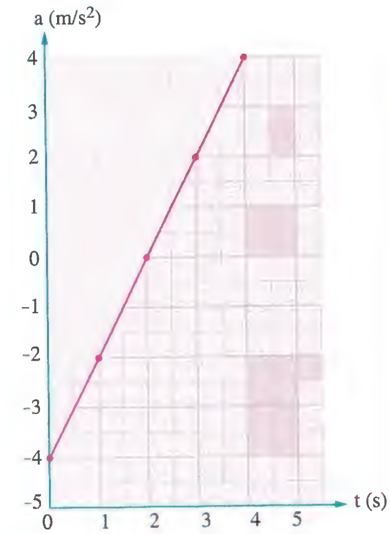
(a) $\frac{9}{1}$ (b) $\frac{3}{1}$ (c) $\frac{1}{3}$ (d) $\frac{1}{9}$

40 Two objects on a frictionless surface are connected with a rope of negligible mass. An external force (F) acted on them as in figure, then the tensions in the rope = ...



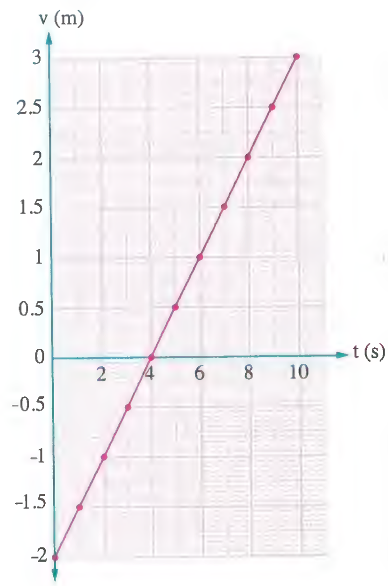
(a) zero (b) 2F (c) F (d) $\frac{F}{3}$

41 The acceleration of a 5 kg object over time is shown in this graph.
What is the net force at 1 s ? ....



(a) – 10 N
(b) – 5 N
(c) – 2.5 N
(d) 5 N

42 A boy is pushing a 50 kg crate across a frictionless surface. The velocity is changing with time as shown in this graph. What is the magnitude of the force that the boy applies to the crate ? ....



(a) 5 N
(b) 10 N
(c) 15 N
(d) 25 N

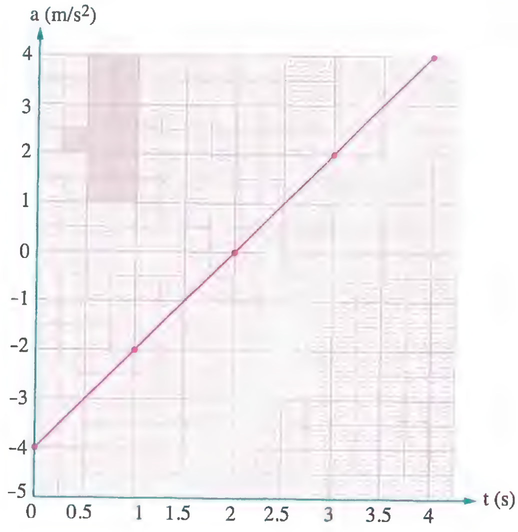
43 The (acceleration - time) graph of an object's motion is shown in this figure. At what time will the forces acting on it become balanced ? ....

ⓐ 0

ⓑ 1 s

ⓒ 2 s

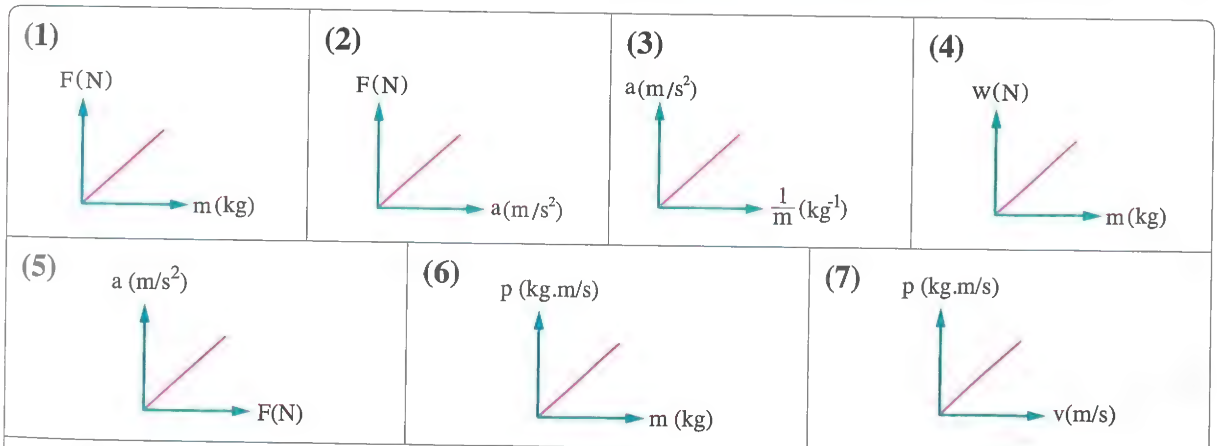
ⓓ 3 s



Second Essay questions

1 **Explain** Newton's first law is a special case of Newton's second law.

2 **Write down the mathematical relation and mention what the slope equals :**



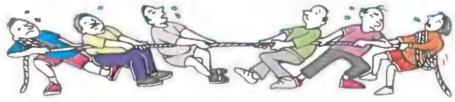
Where : (p) is the momentum, (m) is the mass, (v) is the velocity, (F) is the force, (a) is the acceleration and (w) is the weight.

3 The following figures show three identical cars , each of mass m, **arrange** their maximum accelerations after passing by the traffic light in ascending order assuming that the force of friction is negligible.

4 **In the opposite figure :**

(a) **What happens when** both teams pull the rope with the same force ?

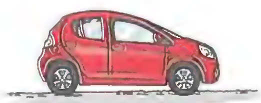
(b) **What happens when** one team pull the rope with a greater force than the other does ?



5 **Would you prefer to** have a piece of gold that weighs 1 N on Earth or one that weighs 1 N on the Moon ? **Explain.** (knowing that : Moon's gravity = $\frac{1}{6}$ Earth's gravity)

6 Two cars x and y move in the same direction under the effect of the same resultant force. If the mass of car y equals the mass of the load on the car x, **so which of** the two cars moves with larger acceleration ?

(x)



(y)

7 **Explain why** car companies have recently added airbags to the cars.

8 If a body moves from rest with uniform acceleration (a) to have momentum (p) after time (t), **prove that** its momentum will be (2 p) after time (2 t) from the beginning of its motion.

Third Problems

1 An eagle of mass 10 kg flies at 20 m/s and a gazelle of mass 50 kg is running at 5 m/s. **Which of them** has greater momentum ? *(The momentum of the gazelle > That of the eagle)*

2 An object of mass 0.5 kg is left to fall freely from the top of a tower where it reached the ground after 4 seconds. **Calculate** its momentum when it touches the ground. ($g = 10\ m/s^2$)

(20 kg.m/s)

3 A ball of mass 0.5 kg is left to fall freely from a height of 20 m. **Calculate** its momentum just before it touches the ground neglecting the resistance of air. *(10 kg.m/s)*

4 Two bodies have masses of 5 kg and 15 kg, the first is travelling by a velocity of 20 m/s. **Calculate** the velocity of the second one if both of them have the same momentum.

(6.67 m/s)

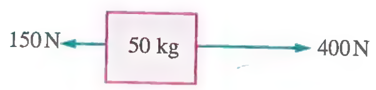
5 **Find** the required resultant force that accelerates a mass of 10 kg moving in a straight line to change its velocity from 54 km/h to 108 km/h during 10 s. *(15 N)*

6. A force acts on a static object of mass 4 kg placed on a horizontal smooth plane and accelerates it uniformly at 2 m/s^2, **find** the magnitude of this force and the time taken by this object to cover a distance of 16 m under the effect of this force. *(8 N , 4 s)*

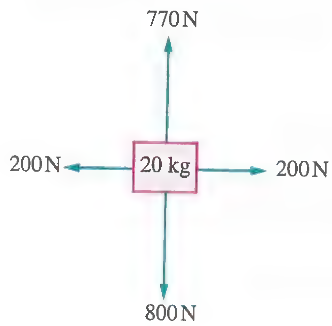
7. **Find** the force that affects an object of mass 30 kg to :
   (a) accelerate it at 3 m/s^2.
   (b) speed it up from rest to 8 m/s during 6 s.
   (c) make it move from rest through 50 m in 5 s. *(90 N, 40 N, 120 N)*

8. A car was moving at velocity 20 m/s in a straight road. The driver applied the brakes to decelerate the car at 5 m/s^2. **Find :**
   (a) The time taken to stop the car and the distance required.
   (b) The type of the force that slowed down the car and the direction of its action.
   (c) The magnitude of the force that stopped the car if the car has a mass of 600 kg.
   (4 s, 40 m, negative and opposite to the direction motion, – 3000 N)

9. **Calculate** the resultant force and the acceleration of each mass in the following figures :



(1)



(2)

(250 N, 5 m/s^2, 30 N, 1.5 m/s^2)

10. A force of 100 N acted on an object of mass 10 kg and changed its velocity from 10 m/s to 20 m/s. **Calculate** the distance that moved by the object during the change in its velocity. *(15 m)*

11. A car of mass 1000 kg was moving in a velocity of 20 m/s. The driver applied the brakes, so it stopped after 10 seconds. **Find :**
    (a) The momentum of the car before using the brakes.
    (b) The momentum of the car after 10 seconds.
    (c) The average force of the brakes acting on the car. *(2×10^4 kg.m/s, 0, – 2000 N)*

12. A car of mass 725 kg was travelling by a velocity of 72 km/h when the driver applied the brakes for 2 s the car was affected by an average force of 5×10^3 N.
    Calculate :
    (a) The change in the momentum of the car during this period.
    (b) The velocity of the car at the moment of releasing the brakes. *(-10^4 kg.m/s, 6.2 m/s)*

13 Two equal forces have acted on two bodies of different masses; $m_1 = 5$ kg and $m_2 = 1$ kg The first body is accelerated at a_1, while the second body has acquired acceleration of $20\ m/s^2$. **Find** the acceleration a_1. *($4\ m/s^2$)*

14 Two equal forces act on two bodies. The first body has acquired acceleration of $8\ m/s^2$ while the velocity of the second body is changed from rest to 48 m/s during 3 s. If the mass of the first body is 5 kg, **what** is the mass of the second body ? *(2.5 kg)*

15 When a body of mass 8 kg went through a rough plane its velocity decreased due to the friction till it has stopped after a distance of 40 m. **Calculate** the friction force. *(– 40 N)*

16 A car of mass 500 kg started motion from rest along a horizontal road by the effect of the engine force that equals 300 N. If the frictional force is 50 N, **find :**

(a) The moving force for the car.

(b) The acceleration of the car motion. *(250 N, $0.5\ m/s^2$)*

17 A car of mass 1200 kg moved from rest under the effect of a force 600 N.

Find :

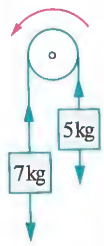
(a) The acceleration by which the car moved.

(b) The velocity of the car after 30 s.

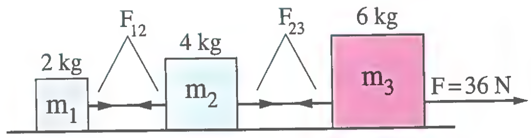
(c) The distance covered by the car after the same time.

(knowing that : $g = 10\ m/s^2$) *($0.5\ m/s^2$, 15 m/s , 225 m)*

18 **Calculate** the acceleration by which the two loads move if the mass of the first load is 5 kg and the second load is 7 kg by neglecting the air resistance. ($g = 10\ m/s^2$) *($1.67\ m/s^2$)*



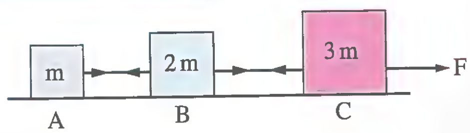
19 Three masses are connected together by weightless threads as shown in figure where they are pulled on a smooth surface by a horizontal constant force to move them by a uniform acceleration. **Find :**



(a) The common acceleration of these masses.

(b) The tension force in each thread. *($3\ m/s^2$, 6 N, 18 N)*

20 A group of three masses as shown in figure moves at a changeable velocity by the effect of a resultant force F = 30 N. **Find :**



(a) The tension force in the thread between (A) and (B).

(b) The tension force in the thread between (B) and (C). *(5 N, 15 N)*

21 A crane pulls a car with a force 3000 N to accelerate it at $3\ m/s^2$. **Find** the mass and weight of the car. ($g = 9.8\ m/s^2$) *(1000 kg , 9800 N)*

22 A body has a mass of 50 kg on the Earth where the acceleration due to gravity = 9.8 m/s^2
Find :

(a) The body's weight on the Earth. (b) The body's mass on the Moon. *(490 N, 50 kg)*

23 **What** is the weight of a space probe of mass 225 kg on the Moon, assuming that the acceleration due to gravity on the Moon = 1.62 m/s^2? *(364.5 N)*

24 A force of 100 N acts on a body to change its velocity from 10 m/s to 20 m/s while moving a distance of 30 m. **Calculate :**

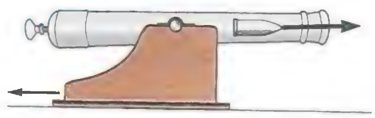
(a) The mass of the body. (b) The weight of the body.

(giving that : the free fall acceleration = 10 m/s^2) *(20 kg, 200 N)*

25 A body of weight 240 N was moving at velocity of 25 m/s. Two seconds later, its velocity became 40 m/s. Assuming that the free fall acceleration = 10 m/s^2, **find** the force acting on that body. *(180 N)*

26 A body of weight 400 N moving with velocity 5 m/s was acted upon by a force 200 N. If the body moved for 3 s and the free fall acceleration = 10 m/s^2, **calculate** the final velocity after 3 s. *(20 m/s)*

27 A missile of mass 3.2 kg is projected from a cannon that is placed horizontally as in the opposite figure. The missile moves with acceleration of 2500 m/s^2 and the cannon recoils with acceleration of 0.76 m/s^2. If the cannon is placed on a frictionless surface, **calculate** the mass of the cannon. *(1.05×10^4 kg)*



28 A bullet of mass 9.1 g penetrates a piece of plastic of thickness 2.3 cm with velocity of 165 m/s, then it comes out from the other side with velocity of 92 m/s. **What** is the average force by which the bullet acts on the piece of plastic ? *(3711.44 N)*

29 A body at rest is affected by a force equals half its weight. **Find :**

(a) Its velocity after 2 s.

(b) The distance covered by it during 2 s.

(assuming that : the acceleration due to Earth's gravity = 10 m/s^2) *(10 m/s , 10 m)*

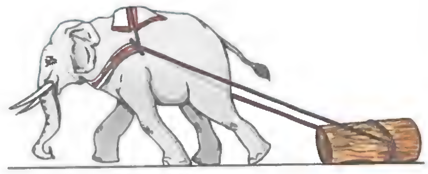
30 An object of mass 1.5 kg is left to fall from the top of a building. If it reached the middle of the building within 5 seconds, **calculate** its momentum at the moment it touches the ground. *(106.07 kg.m/s)*

31 Two bodies of masses 3 kg and 5 kg are at rest, **calculate** the ratio between the required time for both masses to reach the same velocity if both masses are acted upon by the same force. *($\frac{3}{5}$)*

32. A ball falls freely from a tower towards a sandy ground where its velocity when it touches the ground is 90 m/s. **Calculate** the mass of the ball if it penetrates the sand and stops after 1 s where the force of resistance of the sand against the motion of the ball is – 3000 N. ($g = 10\ m/s^2$) *(33.33 kg)*

33. A body of mass 3.2 kg is tied by a rope. **Find** the maximum acceleration that can be acquired by the body during lifting it vertically upwards by the rope if the maximum mass that can be lifted by the rope is 15 kg at rest. (knowing that : $g = 10\ m/s^2$) *(36.88 m/s^2)*

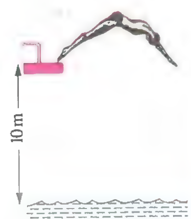
34. An elephant pulls a log of mass 0.5 ton by a rope with uniform velocity along the ground where the rope makes an angle 60° to the horizontal as shown in the figure. Given that the frictional force between the log and the ground is 200 N, **find :**



(a) The tension force in the rope.

(b) The tension force in the rope required to make the log move at acceleration 2 m/s^2. *(400 N, 2400 N)*

35. A diver of mass 50 kg jumps from 10 m high diving board. **Find :**



(a) The diver velocity at hitting the water surface.

(b) The water resistance to the motion of the diver if his motion ends at 2.45 m deep in water. ($g = 9.8\ m/s^2$) *(14 m/s, – 2000 N)*

36. A ball fell freely from a tower onto a sandy soil. Its velocity when reaching the ground is 90 m/s. **Calculate :**

(a) The tower height. (b) The ball's mass if it sank into sand and stopped 1 s later.

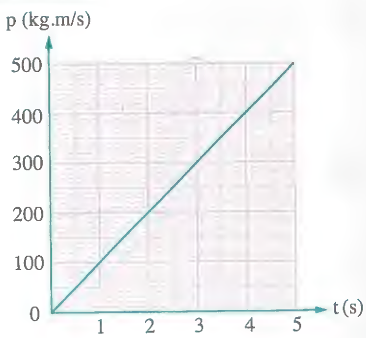
(giving that : the sand resistance to the ball motion is 3000 N , free fall acceleration = 10 m/s^2) *(405 m, 33.3 kg)*

37. If a car of mass 800 kg decelerates by 6 m/s^2 when applying the brakes.

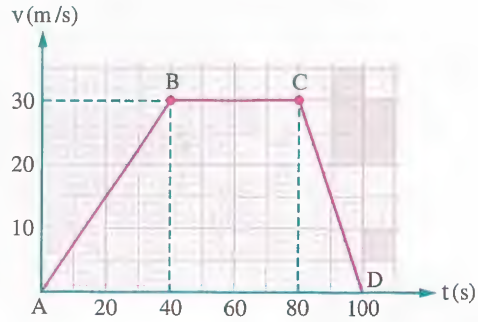
(a) **Calculate** the acting force on the car when the brakes are applied.

(b) If a trailer of mass 400 kg is towed by the car, **calculate** the deceleration of the car when applying the brakes. *(– 4800 N , –4 m/s^2)*

38. The opposite graph represents the change of the momentum (p) with the time (t) of a body of mass 16 kg that acts on it a constant force. **Calculate** the magnitude of this force. *(100 N)*



39 An object of mass 80 kg is moving during 100 s according to the opposite graphical relationship :



(a) **Find** the greatest velocity reached by the object.

(b) **What is the type of** the object motion in the stage AB and the stage BC ?

(c) **Calculate** the force acting on the object in each stage.

(30 m/s, uniform acceleration, uniform velocity, 60 N, 0, – 120 N)

40 A body of mass (m) is affected by a number of different forces according to the following table :

F (N)	10	20	30	40	50
a (m/s^2)	1	2	3	4	5

(a) **Represent these data graphically** where force is on the ordinate while acceleration is on the abscissa.

(b) **From the graph find** the value of the line slope **and mention what** it represents.

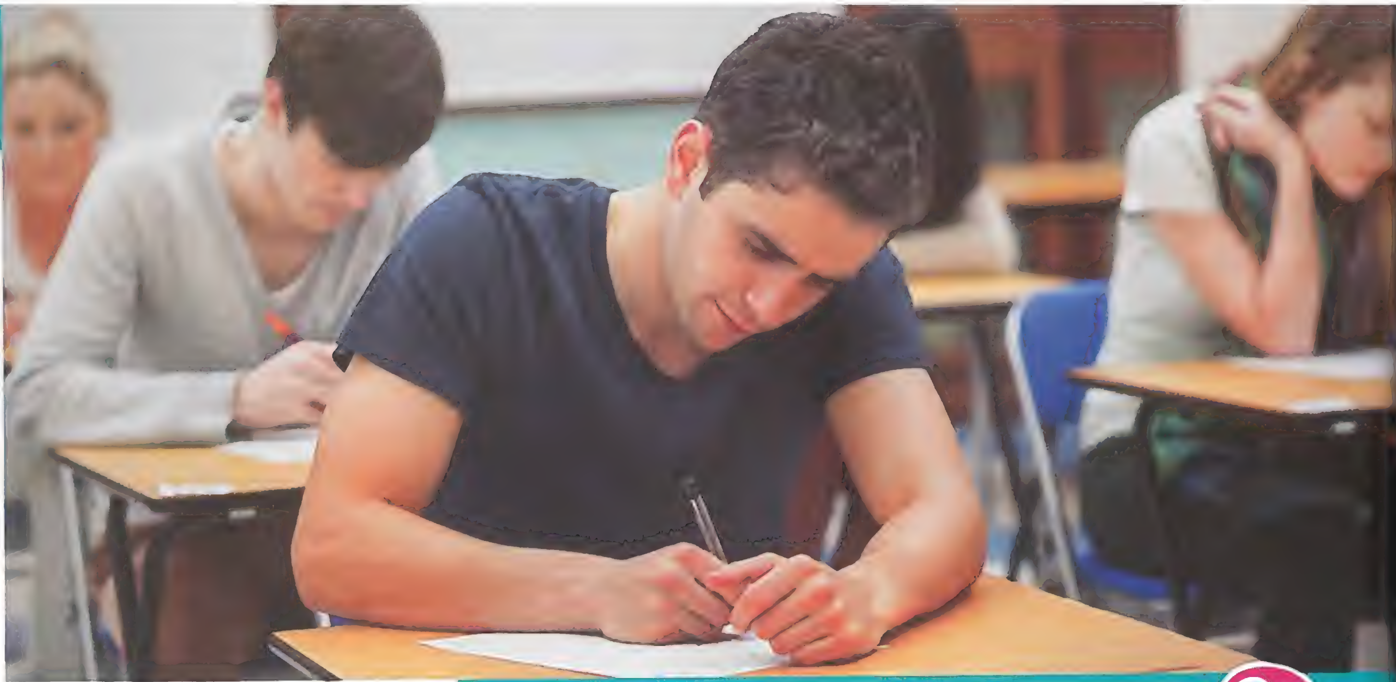
(m = 10 kg)

41 A force acts on a body of mass 16 kg so that the momentum changes according to the following table :

t (s)	1	2	3	4	5
p (kg.m/s)	100	200	300	400	500

(a) **Plot** the graph where (t) is on the x-axis and (p) is on the y-axis.

(b) **From the graph find** the acting force. *(100 N)*



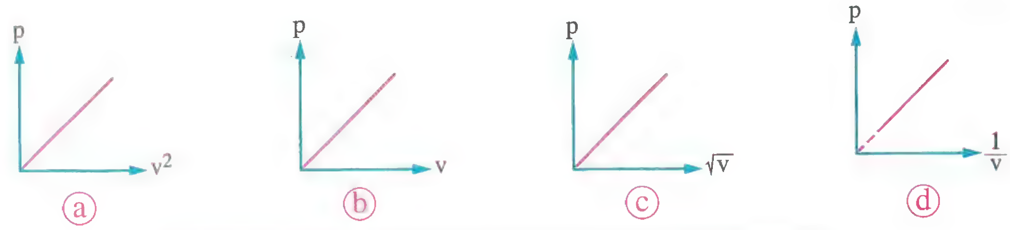
MODEL EXAM ON

Chapter 3

Force and Motion (Momentum - Newton's Second Law)

First Choose the correct answer

1 The graph that represents the relation between the momentum of a body and its velocity is ....



2 A body of mass 40 kg is placed on the surface of the Moon, then its weight on the surface of the Earth is ....

(a) 400 N (b) 392 N (c) 66 N (d) 60 N

3 If a force of 500 N acts on a static car to move it forward for a distance with uniform acceleration, then the value of friction forces is ....

(a) greater than 500 N
(b) less than 500 N
(c) equal to 500 N
(d) the answer can't be defined

4 Small rockets are used to change the velocity of satellites, so if one of these rockets acts on a satellite of mass 7200 kg with a pushing force of 3500 N, then the time interval that is required for the rocket to act on the satellite to increase its velocity by 0.63 m/s is ....

(a) 0.864 s (b) 1.052 s (c) 1.296 s (d) 1.487 s

5. Sand truck moves in a highway under the effect of constant force. If the sand leaked gradually through a slot in the truck, then the truck's acceleration will ....

ⓐ decrease
ⓑ increase
ⓒ remain constant
ⓓ decrease then increase

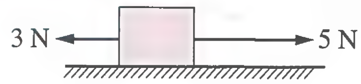
6. The ratio between the acting force on a body and the mass of this body according to Newton's second law is ....

ⓐ 0.5 a
ⓑ a
ⓒ 1.5 a
ⓓ 2 a

7. The acting force on a body and its weight equalize when the body's acceleration is .... the free fall acceleration.

ⓐ quarter
ⓑ one third of
ⓒ half
ⓓ equal to

8. The opposite figure shows a box that moves with constant velocity on a horizontal surface under the effect of two forces, then the friction force is ....



ⓐ 2 N
ⓑ 3 N
ⓒ 4 N
ⓓ 5 N

9. A bowler applies a constant net force of 100 N on a 5 kg bowling ball over a time period of 1.5 s before he releases the ball. If the ball starts from rest, so what will be its final velocity ? ....

ⓐ 5 m/s
ⓑ 10 m/s
ⓒ 20 m/s
ⓓ 30 m/s

10. When a hot liquid evaporates inside a cup, then ....

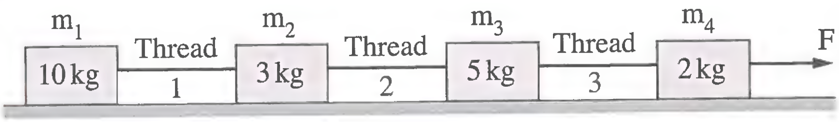
	The mass of the liquid	The weight of the liquid
ⓐ	decreases	decreases
ⓑ	decreases	remains constant
ⓒ	remains constant	decreases
ⓓ	remains constant	remains constant

Second Answer the following questions

11 The following figure shows four masses that are connected with a thread of a negligible mass. The masses are pulled over a frictionless surface by a horizontal force (F), **arrange ascendingly :**

(a) The masses according to their acceleration.

(b) The threads according to the tension force in each of them.



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12 A football player of mass 85 kg is running with a velocity of 5 m/s. If another player pulled him till he stops after covering a distance of 1.25 m, **calculate** the average force that stops the player.

....

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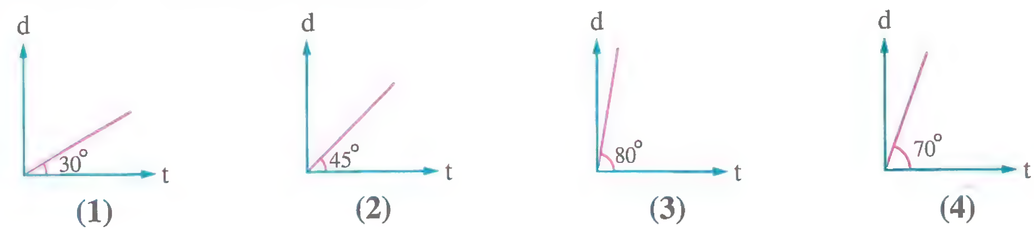
13 The next graphs show the state of a group of bodies that have the same mass and all the graphs are drawn by the same scale of drawing.

Which graph of the following graphs represents the state of the body that has the largest momentum ? **Explain your answer.**



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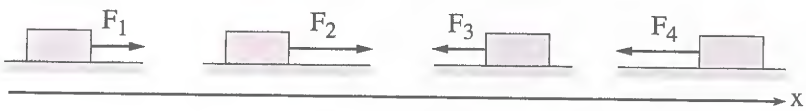
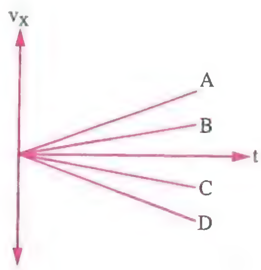
14 Two equal forces act on two bodies of masses 1 kg and 5 kg where the second mass acquire an acceleration of 20 m/s^2. **Calculate** the acceleration of the first mass.

15 Figure (1) shows four cases in each of them there is a horizontal force that acts on the same mass and moves it from rest, while figure (2) represents the change in the horizontal velocity of the mass with the time. So **match each** graphical representation in figure (2) with the force that represents it in figure (1) if $F_2 = F_4 = 2\,F_1 = 2\,F_3$?

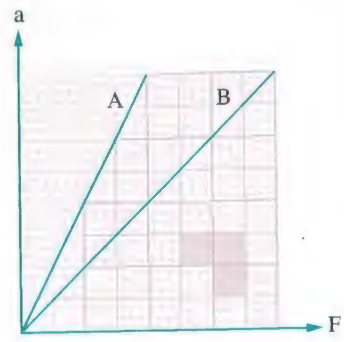


(1)



(2)

16 The opposite graph shows the change of the acceleration with change of the acting resultant force that acts on two different bodies A and B. **Calculate** the ratio between the mass of body A and the mass of body B.



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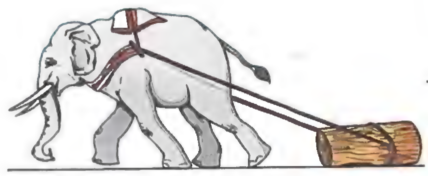
17 An elephant pulls a wooden lump of mass 1 ton on a horizontal surface with a velocity that changes uniformly from 1 m/s to 4 m/s during 2 s. If the friction force between the lump and the ground is 400 N, **calculate** the horizontal component of the tension force in the rope.



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UNIT 3

Circular Motion

Unit objectives

By the end of this unit, the student will be able to :

Chapter 1 :

- Deduce the laws of circular motion.
- Deduce the value of the centripetal acceleration and define its concept.
- Deduce the law of centripetal force.
- Find the magnitude of the centripetal force.

Chapter 2 :

- Deduce the universal (general) gravitation law.
- Deduce the factors of the change in the speed of a satellite around the Earth.
- Explain the revolution of the Moon around Earth in a specific orbit.

Chapter 1 Laws of Circular Motion

- **Circular motion is very common in the universe such as :**
  - Motion of planets around a star.
  - Motion of moons around a planet.

- You have learned through the study of **Newton's second law** that :

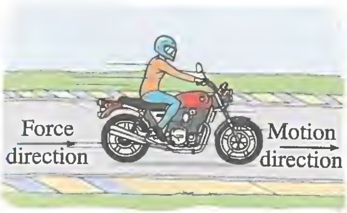
When a force acts on a moving body → it acquires → acceleration → which means that → its velocity changes

, and that change in velocity depends on the direction of the resultant acting force relative to the direction of motion.

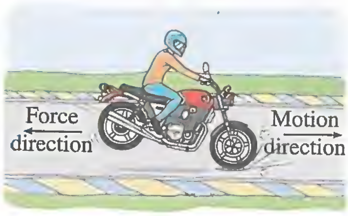
- **If the direction of the resultant acting force is :**

in the same direction of motion	opposite to the direction of motion	perpendicular to the direction of motion
The speed of the moving object increases.	The speed of the moving object decreases.	The speed of the moving object remains unchanged.
The direction of motion does not change.	The direction of motion does not change.	The direction of motion changes.

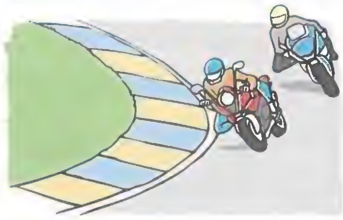
Example



When the motorcyclist pumps more fuel, the motorbike is acted upon by a force in the same direction of motion and accelerates (its velocity increases).



When the motorcyclist applies the brakes, the motorbike is acted upon by a force opposite to the direction of motion and decelerates (its velocity decreases).



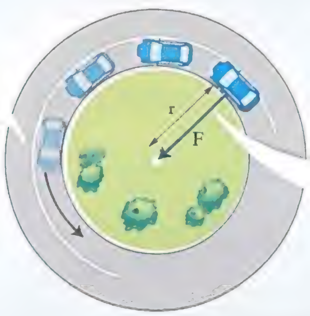
When the motorcyclist leans his body to right or to left, a force is produced normal to the direction of motion causing a change in the direction of motion so that the motorbike moves in a circular path.

As you see for an object to move in a **uniform circular motion**, it must be affected by a constant resultant force that is perpendicular to its path towards the circle's center which is called the centripetal force.

EKB

Uniform circular motion

It is the motion of a body in a circular path with a constant speed and changeable direction.



Centripetal force

It is the force acting continuously in a direction normal to the motion of a body, changing its straight path into a circular path.

Laws of circular motion

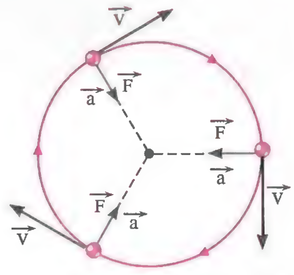
First
Centripetal acceleration

Second
Centripetal force

First Centripetal acceleration

EKB

- When a resultant force (F) acts on a body of mass (m) that moves at speed (v) in a circular path of radius (r) normally to the direction of motion :
  - The magnitude of the velocity (v) remains **constant** along its path.
  - The direction of the velocity **changes** from one point to another on its path.



- The change in the direction of velocity leads to the existence of an acceleration called the **centripetal acceleration (a)**.

Centripetal acceleration :

It is the acceleration acquired by an object moving in a circular path due to the change in the direction of its velocity.

- If the body completes one circular revolution in an interval of time (T) which is called the **periodic time** , the velocity (v) by which the body moves is called the **tangential velocity** and it is given by the relation : $v = \frac{2\pi r}{T}$

  And its direction is always in the direction of the tangent to the circular path.

Periodic time :

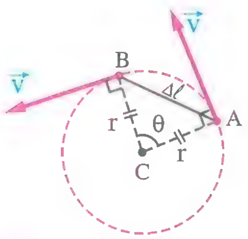
It is the time taken by a body to make one complete revolution.

- If the body completes number N of complete revolutions during time t, then the periodic time of its motion is given by the relation : $T = \frac{t}{N}$

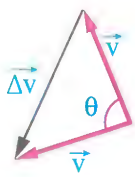
Deducing the centripetal acceleration

- If a body moves from point (A) to point (B) as in the figure, the velocity $(\vec{v})$ changes in direction but maintains a constant magnitude so the change in velocity $(\Delta\vec{v})$ is due to the change in direction only.

Proof



By drawing the triangle of velocities



For illustration

The two triangles are similar because they are isosceles having the same included angle.

From the similarity of triangle (CAB) and the triangle of velocities :

$$\frac{\Delta \ell}{r} = \frac{\Delta v}{v}$$

$$\Delta v = \frac{\Delta \ell}{r} \times v$$

When the body moves from point (A) to point (B) in a period of time (Δt) , so :

$$a = \frac{\Delta v}{\Delta t} = v\,\frac{\Delta \ell}{\Delta t} \cdot \frac{1}{r}$$

$$\because\ v = \frac{\Delta \ell}{\Delta t}$$

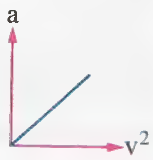
$$\therefore\ \boxed{a = \frac{v^2}{r}}$$

The factors that affect centripetal acceleration (a) :

1 The tangential velocity :

Centripetal acceleration is directly proportional to the square of the tangential velocity at constant radius of the circular path.

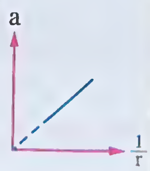
Slope $= \frac{\Delta a}{\Delta v^2} = \frac{1}{r}$

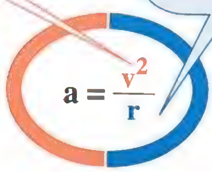


2 The radius of the circular path :

Centripetal acceleration is inversely proportional to the radius of the circular path at constant tangential velocity.

Slope $= \frac{\Delta a}{\Delta\left(\frac{1}{r}\right)} = v^2$





Example 1

A ball that is attached to the end of a rope is moving uniformly in a horizontal circular path of radius 0.6 m. If the ball completes two revolutions in one second, calculate the tangential velocity of the ball and also its centripetal acceleration.

Solution

| $r = 0.6$ m | $N = 2$ | $t = 1$ s | $v = ?$ | $a = ?$ |

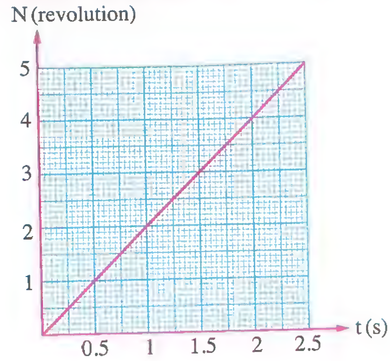
$$T = \frac{t}{N} = \frac{1}{2}\ \text{s}$$

$$v = \frac{2\pi r}{T} = \frac{2 \times \frac{22}{7} \times 0.6}{\frac{1}{2}} = 7.54\ \text{m/s}$$

$$a = \frac{v^2}{r} = \frac{(7.54)^2}{0.6} = 94.75\ \text{m/s}^2$$

Example 2

A body moves in a uniform horizontal circular path of radius 1 m with constant velocity, where the opposite graph shows the number of revolutions made by the body as time passes.
Calculate the tangential velocity of the body and the centripetal acceleration that acts on it.



Solution

r = 1 m | v = ? | a = ?

$$\text{Slope} = \frac{\Delta N}{\Delta t} = \frac{5-0}{2.5-0} = 2 \text{ revolutions/second}$$

$$T = \frac{t}{N} = \frac{1}{\text{Slope}} = 0.5 \text{ s}$$

$$v = \frac{2\pi r}{T} = \frac{2 \times \frac{22}{7} \times 1}{0.5} = 12.57 \text{ m/s} \qquad a = \frac{v^2}{r} = \frac{(12.57)^2}{1} = 158 \text{ m/s}^2$$

Example 3

A body moves in a circular path with a tangential velocity of 10 m/s.
Calculate its average velocity during one quarter of a revolution.

Solution

v = 10 m/s | $\overline{v}$ = ?

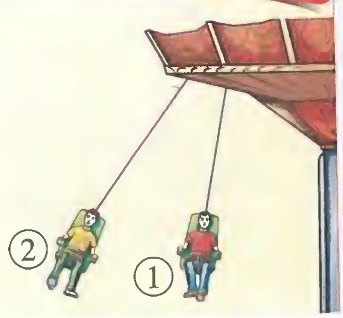
$$\because v = \frac{2\pi r}{T} \qquad \therefore \frac{r}{T} = \frac{v}{2\pi} = \frac{10}{2\pi}$$

$$\overline{v} = \frac{d}{t} = \frac{\sqrt{2}\, r}{\frac{T}{4}} = \frac{4\sqrt{2} \times 10}{2 \times \frac{22}{7}} = 9 \text{ m/s}$$

1 Test yourself

Answered

Choose : The opposite figure shows the swing ride in an amusement park. If two children of equal masses sit on two different places where the distance between the second child and the center of the swing is double the distance between the first child and the center of the swing, then :



(i) The ratio between the velocities of the two children $\left(\frac{v_1}{v_2}\right)$ = ...

ⓐ $\frac{1}{1}$ ⓑ $\frac{1}{2}$ ⓒ $\frac{2}{1}$ ⓓ $\frac{1}{4}$

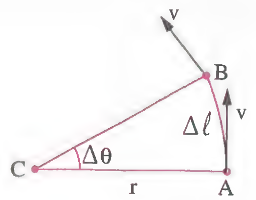
(ii) The ratio between the centripetal acceleration of each child $\left(\frac{a_1}{a_2}\right)$ = ...

ⓐ $\frac{1}{1}$ ⓑ $\frac{1}{2}$ ⓒ $\frac{2}{1}$ ⓓ $\frac{1}{4}$

Enrichment information

Calculating the angular velocity :

If a body moves at a tangential velocity (v) along a circle of radius (r) from point (A) to point (B), covering a distance ($\Delta \ell$) corresponding to an angle ($\Delta\theta$), during time interval (Δt).



Then the value $\left(\frac{\Delta\theta}{\Delta t}\right)$ is known as the **angular velocity (ω)**.

$$\omega = \frac{\Delta\theta}{\Delta t}$$

It is known that the value of the angle in radian equals the ratio between the arc length and the radius of the path.

$$\Delta\theta = \frac{\Delta\ell}{r}$$

$$\therefore \omega = \frac{\Delta\ell}{\Delta t} \times \frac{1}{r} = \frac{v}{r} \qquad \therefore v = \omega r$$

Tangential (linear) velocity = Angular velocity × Radius of the path

Since $v = \frac{2\pi r}{T}$ then : $\omega r = \frac{2\pi r}{T}$

$$\therefore \boxed{\omega = \frac{2\pi}{T}}$$

Second Centripetal force

- When a centripetal force (F) acts on a body of mass (m) to move it in a circular path with a centripetal acceleration (a), so according to Newton's second law the force is given by the relation :

$F = ma$

$$\because a = \frac{v^2}{r} \qquad \therefore \boxed{F = ma = \frac{mv^2}{r}}$$

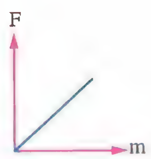
The factors that affect centripetal force (F) :

$$F = \frac{mv^2}{r}$$

1 The object's mass :

Centripetal force is directly proportional to the object's mass at constant tangential velocity and radius of circular path.

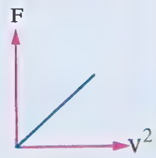
Slope $= \frac{\Delta F}{\Delta m} = \frac{v^2}{r}$



2 The tangential velocity :

Centripetal force is directly proportional to the square of the tangential velocity at constant radius of circular path and object's mass.

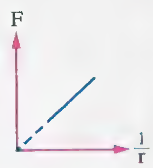
Slope $= \frac{\Delta F}{\Delta v^2} = \frac{m}{r}$



3 The radius of the circular path :

Centripetal force is inversely proportional to the radius of the circular path at constant tangential velocity and object's mass.

Slope $= \frac{\Delta F}{\Delta(\frac{1}{r})} = mv^2$



Example 1

A stone of mass 600 g is attached to a string of length 10 cm and rotated at a speed of 3 m/s. Find the centripetal force. And what do you expect to happen if the greatest tension force in the string just before cutting is 50 N ?

Solution

$m = 0.6$ kg | $r = 0.1$ m | $v = 3$ m/s | $F = ?$

$$F = m\frac{v^2}{r} = 0.6 \times \frac{(3)^2}{0.1} = 54 \text{ N}$$

The string will be cut and the stone will move in a straight line tangent to the circular path at the point where the string has been cut, since the centripetal force that is required to keep the stone in this path by the same velocity is greater than the maximum tension force that the string can withstand.

Example 2

A body of mass 0.5 kg moves along the circumference of a circle of radius 2 m at a constant linear velocity of 10 m/s. Find :

(a) The linear and centripetal acceleration.

(b) The centripetal force that acts on the body.

Solution

m = 0.5 kg | r = 2 m | v = 10 m/s | a = ? | F = ?

(a) The linear acceleration = zero

The centripetal acceleration $= \frac{v^2}{r} = \frac{(10)^2}{2} = 50\ m/s^2$

(b) $F = ma = 0.5 \times 50 = 25\ N$

Practical Experiment 1

Verifying the relation of the centripetal force.

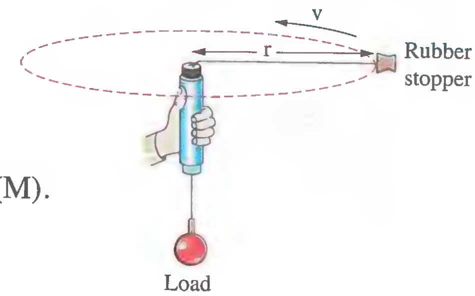
1. Experiment Objective :

Verifying the relation of the centripetal force.

2. Tools :

- Rubber stopper.
- A metal or plastic pipe.
- Stopwatch.
- String.
- A load of mass (M).

3. Procedure :



1. Attach the rubber stopper of mass (m) to a string.
2. Pass the string through the metal or plastic pipe.
3. Attach the other end of the string to a load of mass (M).
4. Move the piece of rubber in a circular path.
5. Measure the periodic time (T) using the stopwatch.
6. Find the centripetal force (tension force in the string) using the relation : $F = F_T = Mg$
7. Find the speed of the rubber's rotation using the relation : $v = \frac{2\pi r}{T}$

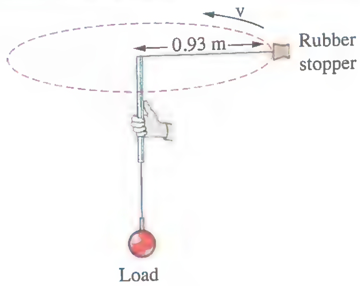
- **Then calculate the value of : $\frac{mv^2}{r}$**

4. Observation and Conclusion :

We find that : $F = Mg = \frac{mv^2}{r}$

Example

If a rubber stopper of mass 13 g is rotated in a horizontal circular path of radius 0.93 m to make 50 revolutions in a time of 59 s. Find the mass of the load which is attached to the other end of the string.
(knowing that : $g = 10\ m/s^2$, $\pi = 3.14$)



Solution

$m = 0.013\ kg$ | $r = 0.93\ m$ | $N = 50$ | $t = 59\ s$ | $g = 10\ m/s^2$ | $M = ?$

Periodic time : $(T) = \frac{t}{N} = \frac{59}{50} = 1.18\ s$

Speed of rotation : $(v) = \frac{2\pi r}{T} = \frac{2 \times 3.14 \times 0.93}{1.18} = 4.95\ m/s$

Centripetal force : $(F) = m\frac{v^2}{r} = 0.013 \times \frac{(4.95)^2}{0.93} = 0.34\ N$

Mass of the load : $(M) = \frac{F}{g} = \frac{0.34}{10} = 0.034\ kg$

2 Test yourself

Answered

A ball of mass 450 g is attached to one end of a rope where it rotates in a circular path of radius 1.3 m on a horizontal smooth table, **calculate** the maximum velocity that can be reached by the ball if the maximum tension force that the rope can withstand is 75 N.

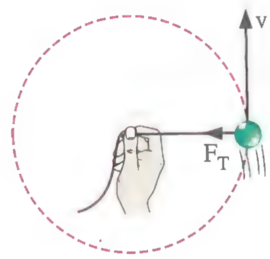
....

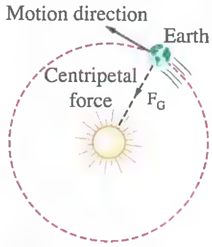
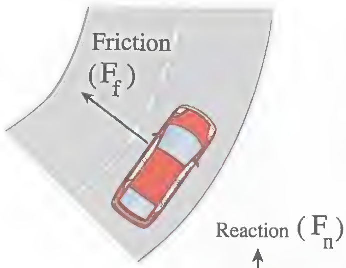
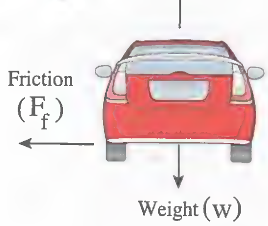
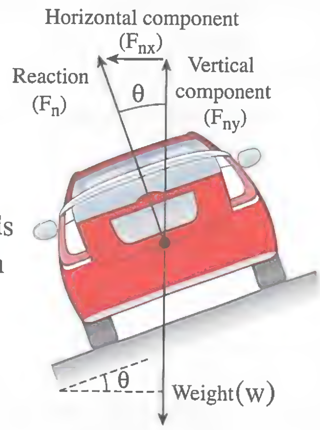
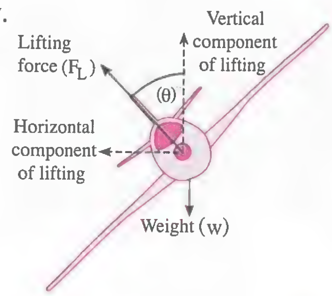
....

....

Types of centripetal force :

The centripetal force is the force that acts continuously perpendicular to the path of a moving body, causing it to move in a circular path. From these forces :

1. Tension force (F_T) :	• When pulling a body by a string or a wire, a tension force is originated. • If this tension force is normal to the direction of motion of the moving body at constant velocity, this force causes the body to move in a circular path. **Which means that** the tension force in the string acts as a centripetal force. 

2. Gravitational force (F_G) :	• The force of attraction between the Sun and the Earth is acting in a direction perpendicular to the path of the Earth. This force causes the Earth to move in a circular path around the Sun. **Which means that** the gravitational force in this case acts as a centripetal force. 
3. Frictional force (F_f) :	• When a car turns in a circular path or a curve, a frictional force between the road and the car tyres is originated.  • This force acts normally to the direction of the car motion towards the center of the circle causing the car to move in a curved path. **Which means that** the frictional force acts as a centripetal force. 
4. The sum of the horizontal components for each of the reaction force and the friction force towards the center of rotation :	• When a car moves in a banked circular path (inclined to the horizontal at an angle θ) it is affected by more than one force, such as : - **The reaction force :** that always acts normally to the car and by resolving this reaction into two components, the horizontal component acts towards the center of the circle and helps the car to move in a curved path. - **The frictional force :** its horizontal component also acts towards the center of the circle and helps the car to move in a curved path.  **Which means that** the centripetal force is the sum of the horizontal components for each of the reaction force and the frictional force which act in a direction towards the center of rotation.
5. The horizontal component of the lifting force :	• The lifting force acts normally to the aeroplane body. • When the aeroplane tilts, the horizontal component of the lifting force acts normally to the direction of motion and towards the center of rotation causing the plane to move in a circular path. **Which means that** the horizontal component of the lifting force on an aeroplane acts as a centripetal force. 

Practical Experiment 2 Demonstrating the motion in a circle.

1. Experiment Objectives :

1. Describing the motion of an object in a circular path.
2. Recognizing the concept of the centripetal force.

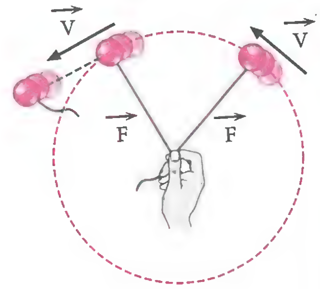
2. Experiment Idea :

- Centripetal force is required to move an object in a circular path.

3. Tools :

- Tennis ball.
- A string (about 120 cm long).
- A pencil.

4. Procedure :

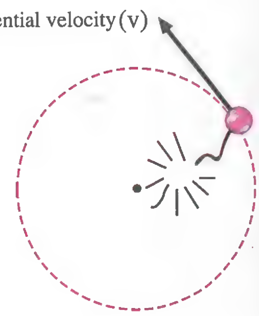


1. Hang the ball to the string.
2. Using a pencil draw a circle with a suitable radius.
3. Put the ball at a point on the circle circumference and hold the string's end such that your hand is at the circle center.
4. Rotate the ball at a suitable speed to make it move along the circumference.
5. Repeat the previous steps using different string lengths. Describe the ball's motion in a table as shown :

String length	Motion description
25 cm	....
50 cm	....
75 cm	....
100 cm	....

6. Set the string free suddenly and notice the direction in which the ball moves.

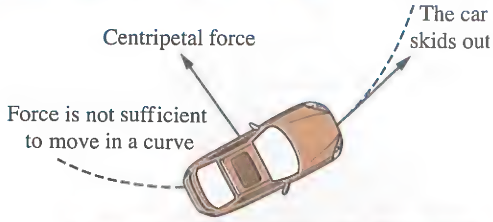
5. Conclusion :



- To keep the ball moving in a circular path, the string should be pulled inwards (the presence of a tension force acts as a **centripetal force**).
- When the string is set free (absence of **centripetal force**), the ball rushes in a direction tangent to the circular path in a straight line at constant velocity due to inertia.
 This velocity is known as the **tangential linear velocity**.

Important Applications on circular motion

1. Designing curved roads :



- It is necessary to calculate the centripetal force when designing the curved roads and railways in order to keep cars and trains moving along this curved path without skidding out.

- If a car moves in a curved slippery road, the frictional forces may not be sufficient to turn the car round the curve. So, the car skids out the road.

- Engineers define certain velocities for vehicles when moving in curves. If the vehicle velocity exceeds the predetermined velocity, the vehicle will need more centripetal force to be kept in this curved path where $\mathbf{F} \propto \mathbf{v^2}$.

- It is forbidden for trucks and trailers to move on some dangerous curves. As the vehicle mass increases, it needs more centripetal force where $\mathbf{F} \propto \mathbf{m}$.

- Slowing down in dangerous curves is a must to avoid accidents. As the radius of curve decreases, the car needs more centripetal force to turn around where $\mathbf{F} \propto \frac{1}{\mathbf{r}}$

2. When moving a bucket half filled with water in a vertical circular path at sufficient speed, the water does not spill out from the opening of the bucket because the centripetal force acting on the water is normal to the direction of its motion. This force changes the direction of velocity without changing its magnitude to keep the water inside the bucket rotating in a circular path.

3. We can make benefit of skidding objects out the circular path when the centripetal force is not sufficient to keep them rotating in the circular path :

1. Making candy floss.

2. Rotating barrels in amusement park.

3. Drying clothes in automatic washing machines : Water droplets adhere to clothes by certain forces. When the dryer rotates at a great velocity, these adhesive forces will not be sufficient to hold these droplets. They separate from the clothes and move tangential to the circular path.

Note :

On using electric sharpener, the glowing metal splints blow in straight lines which are the directions of the tangential velocities of the sharpener rotation.

3 Test yourself

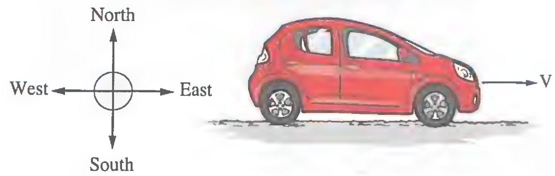
Answered

Choose : If a car starts its motion in a curved slippery road, it may skid out of the road because of the decrease in the ·········· .

(a) friction
(b) velocity
(c) mass
(d) radius of the circular road

First Multiple choice questions

1 The opposite figure shows a car that moves with velocity v towards east. If force F acts on the car, then the car's velocity will ....
(Choose two answers)

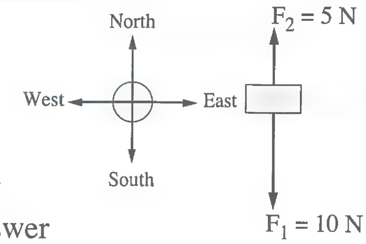


ⓐ decrease when the force F is in the east direction
ⓑ increase when the force F is in the east direction
ⓒ increase when the force F is in the west direction
ⓓ decrease when the force F is in the west direction
ⓔ remain constant

2 When a force acts on a moving body in an opposite direction to its motion, the magnitude of its velocity ....

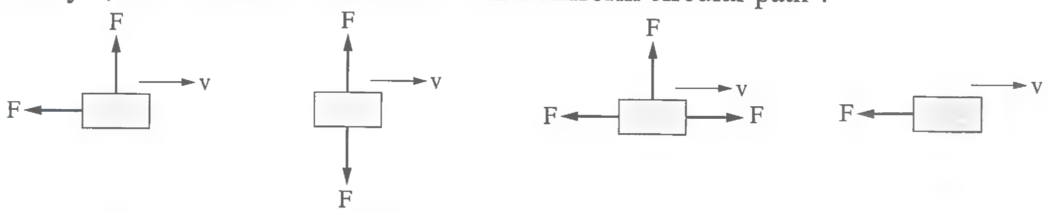
ⓐ decreases without changing direction
ⓑ increases without changing direction
ⓒ remains constant and its direction changes
ⓓ remains constant and its direction doesn't change

3 A body moves towards east on a plane frictionless surface with constant velocity. If two forces F_1 and F_2 act on it as in the opposite figure, then its velocity will change in ....



ⓐ magnitude only
ⓑ direction only
ⓒ magnitude and direction
ⓓ no correct answer

4 The next figures represent the effect of some forces on a body that moves with velocity v, so which of them can rotate in a uniform circular path ? ....

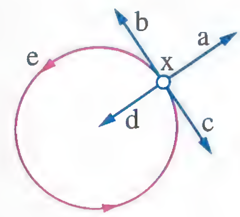


ⓐ ⓑ ⓒ ⓓ

5 The centripetal force acting on a car that moves in a circular path that inclines at an angle with the horizontal is resulted from ....

ⓐ the sum of the vertical components for each of the friction force and the reaction force
ⓑ the sum of the horizontal components for each of the friction force and the reaction force
ⓒ the sum of the vertical component of the friction force and the horizontal component of the reaction force
ⓓ the sum of the horizontal component of the friction force and the vertical component of the reaction force

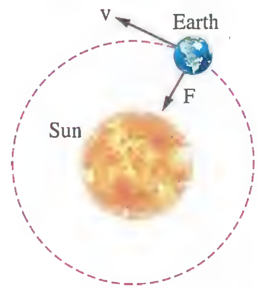
6. A boy ties a stone to a string at its end and moves it in a horizontal plane in the direction of the arrow (e) as shown in the figure.
If the boy leaves the string suddenly when the stone is at x, the stone will move in .... direction (neglecting the gravity).



ⓐ $\overrightarrow{xc}$ ⓑ $\overrightarrow{xb}$ ⓒ $\overrightarrow{xa}$ ⓓ $\overrightarrow{xd}$

---

7. The opposite figure represents the motion of the Earth around the Sun in a circular path where the direction of the centripetal acceleration is .... **(Choose two answers)**



ⓐ in the same direction of the force F
ⓑ perpendicular to the direction of the force F
ⓒ in the same direction of the tangential velocity of the Earth (v)
ⓓ in the opposite direction of the tangential velocity of the Earth (v)
ⓔ perpendicular to the direction of the tangential velocity of the Earth (v)

---

8. If the tangential linear velocity is doubled and the radius of the circular path is also doubled. So, the centripetal acceleration ....

ⓐ decreases to its half ⓑ is doubled ⓒ increases 4 times ⓓ does not change

---

9. Two objects A and B move along the circumference of the same circle with the same velocity where $m_A = 2\ m_B$, so the centripetal acceleration of A is .... that of B moves.

ⓐ equal to ⓑ double ⓒ half ⓓ quarter

---

10. A car moves around a curve of radius 100 m with constant speed 20 $m.s^{-1}$.
So, its centripetal acceleration equals .... $m.s^{-2}$.

ⓐ 4 ⓑ 2 ⓒ 5 ⓓ 2.5

---

11. When a body moves in a uniform circular motion along the circumference of a circle of radius (r), so .... **(Choose two answers)**

ⓐ the centripetal force acts on changing the velocity direction
ⓑ the body moves with constant speed
ⓒ the magnitude of the body's velocity = Centripetal acceleration × r
ⓓ the body's centripetal acceleration is in the same direction of motion
ⓔ the direction of the linear velocity is towards the center of the circular path

---

12. If the tangential velocity of a body that moves in a circular path is 7 m/s where it makes 4 revolutions in two minutes, so the radius of the circular path equals ....

ⓐ 30.6 m ⓑ 33.4 m ⓒ 25 m ⓓ 66.8 m

13 If the radius of a circular orbit is increased to four times its original value, the centripetal force required to make the speed of the body constant would be ....

(a) decreased to half its value (b) unchanged
(c) increased to double its value (d) decreased to quarter its value

14 If an object of mass 6 kg moves in a circle of circumference 6 π with constant speed 10 m/s, so the centripetal force that acts on the body is ....

(a) 400 N (b) 200 N (c) 180 N (d) 50 N

15 A man of mass 50 kg rides a bicycle on a curved road of radius 30 m with a speed of 2 m/s. If the centripetal force that acts on both the man and the bicycle is 10 N, so the mass of the bicycle is ....

(a) 25 kg (b) 50 kg (c) 75 kg (d) 100 kg

16 The ratio between the centripetal forces acting on two bodies of equal masses when the first body moves with a speed of 5 m/s in a circle of diameter 4 m and the second body moves with a speed of 10 m/s in a circle of diameter 8 m is ....

(a) $\frac{2}{3}$ (b) $\frac{1}{4}$ (c) $\frac{1}{3}$ (d) $\frac{1}{2}$

17 A stone of mass 4 kg that is tied to a string of length 10 m rotates in a horizontal circle. If the tension force in the string is 160 N, so the stone speed is ....

(a) 400 m/s (b) 100 m/s (c) 20 m/s (d) 10 m/s

18 If an object moves in a circular path, then all the following statements are correct except ....

(a) the centripetal force changes the direction of motion

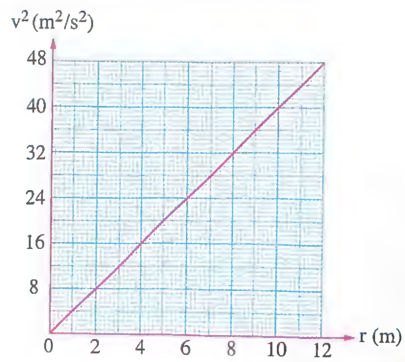
(b) the centripetal force increases the velocity of the object

(c) the acceleration = $\frac{v^2}{r}$

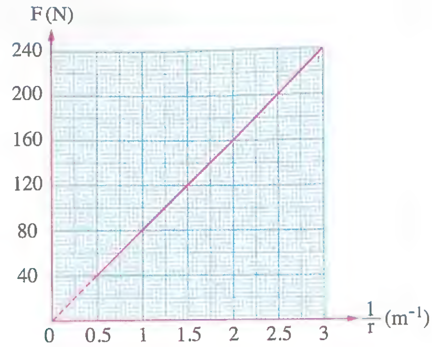
(d) the velocity = $\sqrt{ar}$

19 The opposite graph represents the relation between the square of the tangential velocity (v^2) of a body that moves in a uniform circular path and the radius (r) of the path, so the centripetal acceleration of the body is ....

(a) 2 m/s^2 (b) 4 m/s^2
(c) 6 m/s^2 (d) 8 m/s^2



20 The opposite graph represents the relation between the centripetal force (F) that acts on a body of mass 5 kg moving in a uniform circular path with tangential velocity v and the reciprocal of the radius of this path ($\frac{1}{r}$), so .... **(Choose two answers)**



ⓐ the tangential velocity of the body equals 2 m/s

ⓑ the tangential velocity of the body equals 4 m/s

ⓒ the tangential velocity of the body equals 16 m/s

ⓓ the momentum of the body equals 20 kg.m/s

ⓔ the momentum of the body equals 80 kg.m/s

---

21 In one of the amusement park games, the chairs rotates in a uniform circular path. If one of the chairs is 1.5 m away from the center and another chair is 2 m away from the center and both of them are on the same straight line away from the center, so which of them has the largest tangential velocity ? ....

ⓐ The chair that is 1.5 m away from the center

ⓑ The chair that is 2 m away from the center

ⓒ Both of them have the same velocity

ⓓ The periodic time must be given to determine the answer

---

22 A racing car can accelerate by changing ....

ⓐ its direction only　　ⓑ its speed only

ⓒ either its direction or its speed　　ⓓ its direction and its speed

---

23 A body is revolving with a constant speed in a circle. If its direction of motion is reversed but the speed remains the same, then which of the following statements is true ? ....

ⓐ The centripetal force will not suffer any change in magnitude

ⓑ The centripetal force will have its direction reversed

ⓒ The centripetal force will suffer change in direction

ⓓ The centripetal force would be doubled

---

24 The Moon takes 27.3 days to orbit the Earth at an average radial distance of 385000 km from the center of the Earth. What is the acceleration of the Moon ? ....

ⓐ 2.73×10^{-3} m/s^2　　ⓑ 4.96×10^{-3} m/s^2

ⓒ 9.8×10^{0} m/s^2　　ⓓ 1.94×10^{-3} m/s^2

25 A circus player intended to ride a motorcycle of mass (m) in a vertical loop. Assuming that the loop is a circle with radius (r), what is the least speed (v) the player should have at the top of the loop to remain in contact with it ? ....
(g = acceleration due to gravity)

ⓐ $v = gr$ ⓑ $v = g / r$ ⓒ $v = \sqrt{gr}$ ⓓ $v = (gr)^2$

26 In the display window of a toy store at the mall, a battery-powered plane is suspended from a string and flying in a horizontal circle. The 631 gram plane makes a complete circle every 2.15 seconds. The radius of the circle is 0.95 m. Determine the centripetal force acting upon the plane ? ....

ⓐ 5.13 N ⓑ 3.45 N ⓒ 5.7 N ⓓ 10.3 N

27 The maximum frictional force between the tyres of a car and the road is 0.5 the weight of the car. If the car negotiates a curve of radius 10 meter, so its velocity is .... ($g = 9.8\ m/s^2$)

ⓐ 10 m/s ⓑ 7 m/s ⓒ 4.9 m/s ⓓ 14.2 m/s

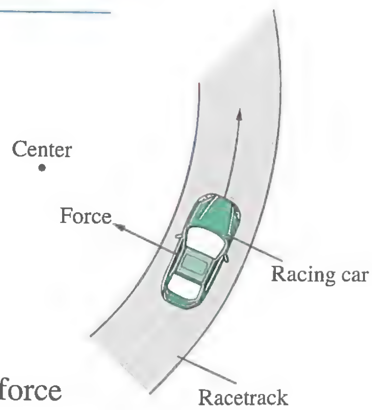
28 A racing car of mass 10^2 kg goes around a circular track (horizontal) of radius 10 m. If the maximum thrust that the track can withstand is 10^5 N, so the maximum speed that the car can go around with is ....

ⓐ 10 m/s ⓑ 100 m/s ⓒ 50 m/s ⓓ 20 m/s

29 If an aircraft executes a horizontal loop of radius 1 km with a steady speed of 900 km/h, so the ratio of its centripetal acceleration to the acceleration due to gravity is .... ($g = 10\ m/s^2$)

ⓐ 9.2 ⓑ 6.25 ⓒ 5 ⓓ 8.25

30 A racing car moves round a circular part of a racetrack.



(i) The force that acts toward the center of the circular part of the racetrack is caused by ....

ⓐ air resistance ⓑ friction
ⓒ gravity ⓓ lifting

(ii) The force is called ....

ⓐ centripetal force ⓑ circular force
ⓒ perpendicular force ⓓ gravitational force

(iii) If another racing car has a greater mass and travels at the same speed around the same racetrack, then the force will need to ....

ⓐ decrease ⓑ stay the same ⓒ increase ⓓ vanish

(iv) When the racing car goes faster, the force will need to ....

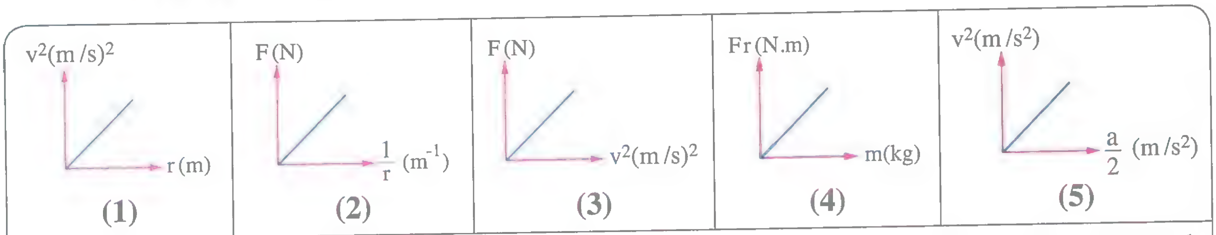
ⓐ decrease ⓑ stay the same ⓒ increase ⓓ vanish

31 A planet of mass 10^{20} kg rotates in a circular path such that its displacement within quarter cycle is $\sqrt{2} \times 10^{10}$ m and covers half a cycle within 10^6 s. Then the centripetal force acting on the planet is ....

a) $2\pi \times 10^{10}$ N b) $\pi \times 10^{20}$ N c) $\pi^2 \times 10^{18}$ N d) $\sqrt{\pi} \times 10^{30}$ N

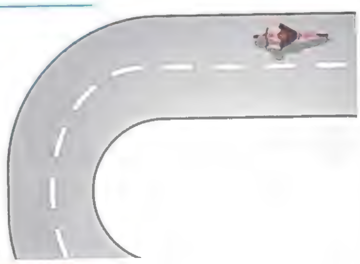
Second Essay questions

1 **Write down the slope of the straight line and the mathematical relation for each of the following :**



(where : (v) is the tangential velocity, (r) is the radius of the circular path, (a) is the centripetal acceleration, (F) is the centripetal force and (m) is the mass of the moving body)

2 In the opposite figure, there is a bicycle driver that moves in the shown road. **What you advise him to do** to keep moving in the curved road without skidding out from it ? **Explain your answer.**

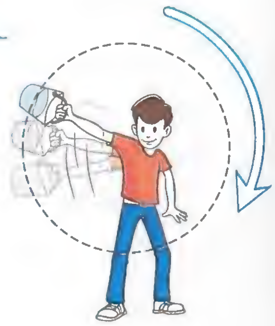


3 On rotating a stone attached to the end of a string in a circular path. **What** is the direction of the force acting on the stone ? **What** is its effect ? **What** is the direction of motion if the string is cut ?

4 **What** is the direction of the force by which the safety belt affects on the car driver when the car turns ?

5 **Which point** on the Earth's surface has the largest tangential velocity relative to the Earth's axis ? **Is the point** located on the equator or on the tropics of Capricorn and Cancer ? **And why ?**

6 **Would** the water be kept inside the bucket when you rotate it in a vertical plane as shown in the figure ? **Explain your answer.**



7 **Explain the following statements :**

(1) Although a body moving in a uniform circular motion and acquires an acceleration, its linear speed is constant.

(2) The Earth rotates around the Sun in the same orbit.

(3) • When a car moves in a curved road, it maintains its curved path and does not skid.
• The car does not slip on moving in a curved path.

(4) The car that moves in a curved path that inclines on the horizontal with an angle doesn't skid.

(5) On designing the curved paths in roads and railways we must take into account the centripetal force.

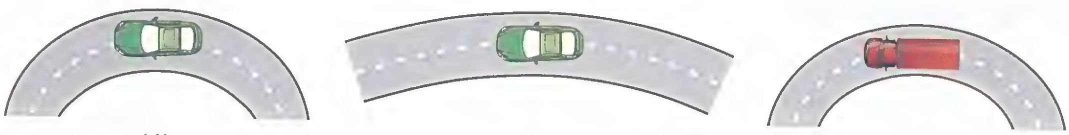
(6) It is recommended to prevent driving heavy trucks on dangerous curved roads.

---

8 The driving instructor assured that the trainees should decrease the velocity of the car before entering a curved road to maintain the safety of the car and the safety of the driver. From your study of the circular motion, **what is the reason of this ?**

---

9 The next figures shows three cars (1) , (2) and (3) that move in three curved road with the same velocity. If the mass of each of car (1) and car (2) is m and the mass of car (3) is 3 m and the roads of the two cars (1) and (3) have the same radius which is double the radius of the road of car (2), **arrange** the cars in descending order according to the possibility of slipping. **Explain your answer**.



(1) (2) (3)

---

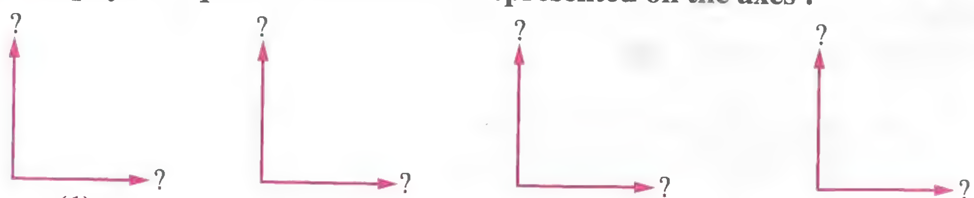
10 A car starts its motion in a curved slippery road, where the driver notices that the car skids out of the curved road. **Explain.**

---

11 **What are the results of** the small diameter curves in the highways ?

---

12 **You have four graphs under each of them a statement, draw these graphs and write down the physical quantities which are represented on the axes :**



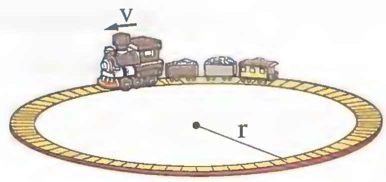
(1) The slope gives the centripetal force

(2) The slope equals $\frac{v^2}{r}$

(3) The slope equals $\frac{m}{r}$

(4) The slope equals mv^2

13. The figure shows a train that moves in a circular path of radius 1 m. If the train makes a complete revolution in 12 s, **complete :**



(a) The path of one revolution is determined from the relation : ℓ = ... m

(b) The velocity can be determined from the relation : v = ... m/s

(c) The centripetal acceleration is determined from the relation : a = ... m/s^2

Third Problems

1. An object of mass 5 kg moves in a circle of radius 2 m at a uniform speed of 5 m/s. **Find each of :**

(a) The centripetal acceleration. (b) The centripetal force.

(c) The linear acceleration. *(12.5 m/s^2, 62.5 N , 0)*

2. A bicycle rider moves in a circular path at a tangential velocity of 13.2 m/s. If the radius of the path is 40 m and the centripetal force keeping the bicycle in a circular path equals 377 N, **calculate** the mass of both the bicycle and the rider. *(86.5 kg)*

3. Centripetal force of 1800 N acts on a body of mass 10 kg to move it in a circular path of radius 5 m, **find :**

(a) The velocity of the body.

(b) The centripetal acceleration. *(30 m/s, 180 m/s^2)*

4. A car of mass 750 kg moves in a circle of diameter 80 m. If the centripetal force acting on the car is 7500 N, **find** the speed of the car. *(20 m/s)*

5. If the centripetal acceleration for an object is 10 m/s^2, **calculate** the centripetal acceleration for the same object if its velocity is doubled and its radius of rotation decreased to half its value. *(80 m/s^2)*

6. A racing car of mass 905 kg moves in a circular path of circumference 3.25 km. **Calculate** the tangential velocity of the car if the force required to keep the circular motion of the car = 2140 N *(34.98 m/s)*

7. A car of mass 1000 kg is moving at a constant speed of 5 m/s in a curved path of radius 50 m. **Calculate** the centripetal frictional force that keeps the car moving in the curved path. *(500 N)*

8. An object of mass 0.01 kg moves in a circular path of radius 150 cm. If it takes 3 s to make a complete revolution, **calculate** the magnitude and direction of the centripetal force. *(0.066 N, to the center)*

9 A body of mass 2 kg is attached to the end of a string to rotate in a horizontal circular path of radius 1.5 m. So as to make 3 revolutions in one second, **calculate :**

(a) The linear tangential velocity. (b) The centripetal acceleration.

(c) The tension force in the string.

(28.27 m/s, 532.79 m/s^2, 1065.58 N)

10 A body of mass 100 g moves along the circumference of a circle of radius 50 cm at a uniform circular motion. If it takes a time of 90 s to make 45 complete revolutions, **calculate :**

(a) Its periodic time. (b) Its linear velocity.

(c) Its centripetal acceleration.

(2 s, 1.57 m/s, 4.9 m/s^2)

11 A car in the amusement park of mass 200 kg moves in a circular path with velocity 10 m/s. If the centripetal force acting on it is 2000 N, **find :**

(a) The radius of rotation. (b) Its centripetal acceleration.

(10 m, 10 m/s^2)

12 A helicopter toy of mass 100 g flies in a circular path of radius 1 m and rotates at a rate of 100 revolutions in 20 s. **Calculate :**

(a) The linear tangential velocity of the toy. (b) The centripetal acceleration.

(c) The centripetal force.

(31.4 m/s, 985.96 m/s^2, 98.596 N)

13 Nermeen tied a ball of mass 0.2 kg to the end of a rope of length 1 m. She makes the ball move in a circle by holding the other end with a suitable movement from her hand with linear velocity of 8 m/s. If the rope withstands a tension force of 15 N, **will** the rope be cut ? **And why** ?

(The rope will not be cut)

14 An object moves in a circular path of diameter 4 m with a linear velocity of 10 m/s , **calculate :**

(a) Its displacement through one complete revolution.

(b) Its periodic time.

(0, 1.3 s)

15 An object of mass 0.2 kg moves in a circular path. If it makes $\frac{3}{4}$ revolution in 0.3 s and its displacement is 6 m, **calculate :**

(a) The radius of the circular path.

(b) The tangential velocity of the object.

(4.24 m, 66.6 m/s)

16 A body moves along the circumference of a circle, where it covers $\frac{1}{4}$ cycle in 0.2 s and makes a displacement of $8\sqrt{2}$ cm. **Find** the radius of the circle and the tangential velocity.

(8 cm , 0.628 m/s)

17 An object of weight 100 N moves with a velocity of 10 m/s in a circular path of radius 10 m , if the acceleration due to gravity is 10 m/s^2, **find :**

(a) The centripetal acceleration. (b) The required time for two revolutions.

(c) The displacement in half a revolution.

(d) The centripetal force.

(10 m/s^2, 12.6 s, 20 m, 100 N)

18 A rock of mass 600 g is attached by a thread of length 10 cm. If the rock was made to move in a horizontal circle at a steady speed of 3 m/s :

(a) **Calculate** the centripetal force.

(b) **What will happen** if the thread can't withstand a tension more than 30 N ?

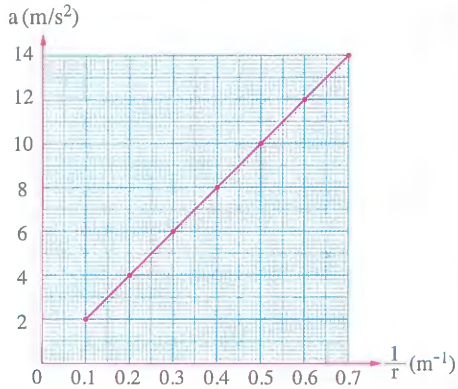
(54 N , Will be cut)

---

19 If the centripetal force that keeps a car in a circular road of radius 500 m equals 0.08 of the car's weight, **calculate** the maximum velocity by which the car can move on that road. (where : $g = 10\ m/s^2$) *(20 m/s)*

---

20 The opposite graph represents the relation between the centripetal acceleration (a) of a body that moves in a circular path and the reciprocal of the radius of this path $(\frac{1}{r})$, **calculate** the tangential velocity by which the body moves. *(4.47 m/s)*



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21 The following table represents the relation between the centripetal acceleration of a body moving in a circular path and square of its velocity :

a (m/s^2)	1	2	3	5	6	8	10
v^2 (m^2/s^2)	100	200	300	500	600	800	1000

(a) **Plot** the graph relating (a) on y-axis and (v^2) on x-axis.

(b) **From the graph find** the radius. *(100 m)*

---

22 An object of mass (m) moves in a circular path of radius 2 m. The following table shows the relation between the object's velocity and the centripetal force acting on it :

F (N)	6	24	54	96	150
v (m/s)	2	4	6	8	10

(a) **Draw** a graph relating (F) on the y-axis and (v^2) on the x-axis.

(b) **From the graph find :**

1- The object's velocity when the centripetal force = 90 N

2- The object's mass. *(7.7 m/s , 3 kg)*

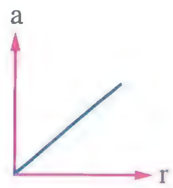
MODEL EXAM ON

Chapter 1

Laws of Circular Motion

First Choose the correct answer

1 The graph that represents the relation between the centripetal acceleration of a body that moves in a circular path and the radius of the circular path at constant tangential velocity is ....



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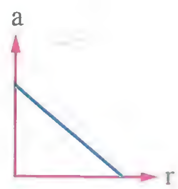

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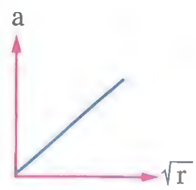

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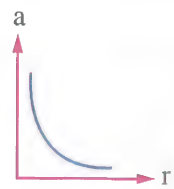

ⓓ

2 Two bodies of the same mass move in two different orbits (A) and (B). If the radius of orbit (A) is double that of orbit (B) and the velocity of the body in orbit (A) is double that of the body in orbit (B), then the ratio between the centripetal force that acts on the body in orbit (A) to that in orbit (B) is ....

ⓐ $\frac{1}{1}$ ⓑ $\frac{2}{1}$ ⓒ $\frac{1}{4}$ ⓓ $\frac{1}{2}$

3 The opposite figure shows two bikes ①, ② that move with two different velocities of constant magnitude in a circular racetrack. If the two bikes reach the end of the race at the same moment, so which of them has larger tangential velocity ? ....

ⓐ Bike ①
ⓑ Bike ②
ⓒ Both have the same velocity
ⓓ The periodic time must be known to determine the answer

4. A body of mass 0.01 kg moves in a circular path of radius 150 cm. If the body makes one revolution in 3 s, so the centripetal force is ....

(a) 0.066 N in a direction tangent to the circular path

(b) 6.585 N in a direction tangent to the circular path

(c) 0.066 N towards the center of the circular path

(d) 6.585 N towards the center of the circular path

---

5. If a body moves in a uniform circular path with constant tangential velocity of 2.2 m/s where it completes 6 revolutions in a minute, then the radius of the path equals ....

(a) 3.5 m (b) 7 m (c) 10.5 m (d) 12 m

---

6. A body of mass 0.1 kg is moving in a uniform horizontal circular path with a velocity of 2 m/s, so the change in its momentum after completing half a revolution equals ....

(a) zero (b) 0.2 kg.m/s (c) 0.4 kg.m/s (d) 0.8 kg.m/s

---

7. If a stone that is attached to a thread of length 0.4 m is rotated in a horizontal plane where its periodic time is 0.2 s, then its centripetal acceleration equals .... m/s^2.

(a) $20\pi^2$ (b) $40\pi^2$ (c) $2\pi^2$ (d) $8\pi^2$

---

8. If a washing machine has a centripetal acceleration of 4302 m/s^2 and a radius of 20 cm , then it completes 7000 revolutions in ....

(a) 1 minute (b) 3 minutes (c) 5 minutes (d) 7 minutes

---

9. Body A moves in a circular path of radius r_A and body B moves in a circular path of radius r_B where the two bodies move with the same velocity. If the two bodies are identical and the ratio between their periodic times $\left(\frac{T_A}{T_B}\right)$ is $\frac{1}{2}$, so the ratio between their centripetal forces $\left(\frac{F_A}{F_B}\right)$ is ....

(a) $\frac{2}{1}$ (b) $\frac{1}{1}$ (c) $\frac{1}{2}$ (d) $\frac{1}{8}$

---

10. A particle moves in a uniform circular path of radius 25 cm due to the effect of a centripetal force that equals numerically 4 times the particle's mass, so the particle's tangential velocity after quarter a revolution is ....

(a) 0.5 m/s (b) 1 m/s (c) 1.5 m/s (d) 2 m/s

Second Answer the following questions

11. A body moves with constant speed but it has an acceleration, **explain this.**

....

12. A body of mass m moves in a uniform circular path of radius r, where it completes one revolution in time T. **Prove that** the centripetal force that acts on the body is given by the relation : $F = \frac{4\pi^2 mr}{T^2}$

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13. **Calculate** the tangential velocity of a body that moves in a uniform circular path, if the product of its centripetal acceleration and the radius of the path equals 16 m^2/s^2.

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14. While you are walking in a road, you notice a sign that warns the heavy trucks from the danger of the next curves in the road. **Explain this** from your study of the circular motion.

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15. A ball of mass 0.25 kg is attached to one end of a rope where it rotates with a linear velocity of 5 m/s in a uniform cirular path. If the distance between the center of the ball and the center of the path is 1 m and the maximum tension force that the rope can withstand is 12 N, **will the rope be cut ? And why ?**

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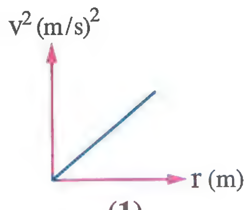
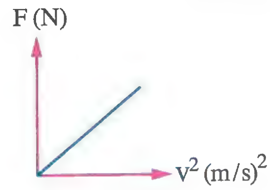
16 **Write down the mathematical relation that represents each of the following graphs and mention the slope of each of them :**



(1)



(2)

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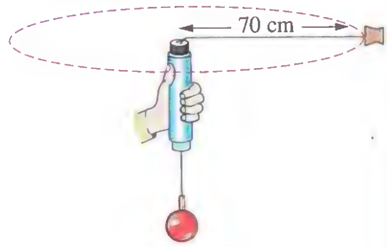
17 In the opposite figure there is a body of mass 43.75 g that moves in a horizontal circular path of radius 70 cm where it completes 25 revolutions in 40 s.

Calculate the mass of the load that is attached to the other end of the string. ($g = 10\ m/s^2$)



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Chapter 2

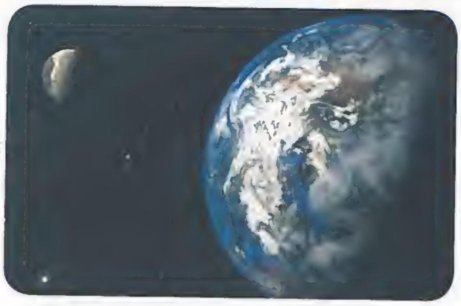
LESSON ONE

Universal Gravitational Force

The universe is in a state of perpetual motion :

EKB

1. **The Moon** rotates around the Earth.



2. **The planets** rotate around the Sun.

3. **The Sun** rotates around the center of the galaxy.

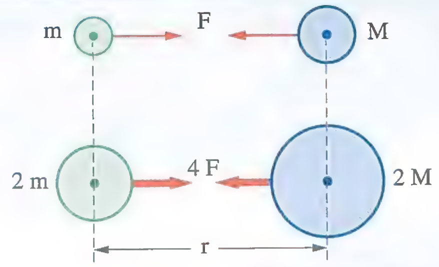
All these celestial bodies move in circular motion or roughly circular motion.

⦿ Isaac Newton had concluded some basic assumptions that helped him to formulate the general gravitational law, of these assumptions :

- There is a mutual attraction force between the Moon and the Earth that causes the rotation of the Moon around the Earth.
- There is attraction force (gravitational attraction) between any two bodies in the universe and this force depends on :

Isaac Newton

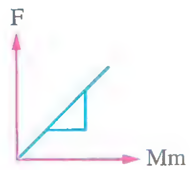
1 The mass of the two bodies



Where the attraction force between two bodies is directly proportional to the product of their masses at constant distance between the centers of the two bodies.

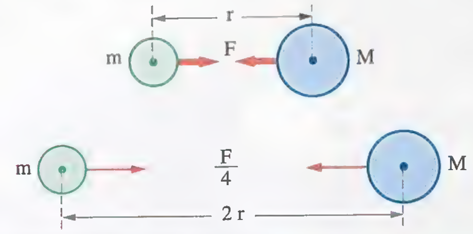
That means

$$F \propto Mm$$



$$\text{Slope} = \frac{\Delta F}{\Delta (Mm)} = \frac{G}{r^2}$$

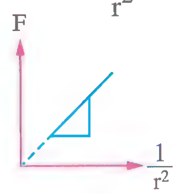
2 The distance between the centers of the two bodies



Where the attraction force between two bodies is inversely proportional to the square of the distance between the centers of the two bodies at constant masses.

That means

$$F \propto \frac{1}{r^2}$$



$$\text{Slope} = \frac{\Delta F}{\Delta (\frac{1}{r^2})} = GMm$$

$$F \propto \frac{Mm}{r^2}$$

The mathematical expression for the general gravitational law

$$F = G\frac{Mm}{r^2}$$

G	r	M	m
The constant of proportionality which is called the general gravitational constant	The distance between the centers of the two bodies	The mass of the first body	The mass of the second body

And according to this , Newton formulated the general gravitational law as follows :

The general (universal) gravitational law :

"A body in the universe attracts another body by a force which is directly proportional to the product of their masses and inversely proportional to square the distance between their centers".

Gravitational constant (G)

Definition: A universal constant that numerically equals the mutual attraction force between two bodies each of mass 1 kg and square the distance between their centers is 1 m^2.

The general formula: $G = \frac{Fr^2}{mM}$

The measuring unit: $N.m^2/kg^2$ (or) $m^3/kg.s^2$

The dimensional formula: $M^{-1} L^3 T^{-2}$

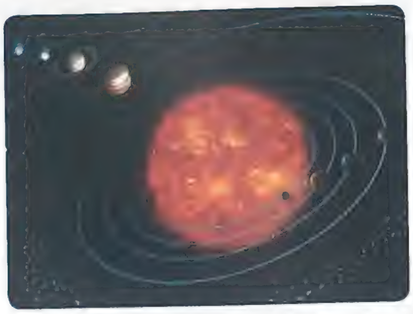
The numerical value: $6.67 \times 10^{-11} m^3 /kg.s^2$

Notes :

1. The gravitational law is known as the universal gravitational law.
   That is due to the general application of the law where it describes the gravitational force of the Earth on the objects which exist on its surface and the force that keeps cosmic objects rotate around it.
2. The gravitational attraction force obviously exists between the cosmic objects, while it is unnoticeable between ordinary objects on the Earth (like two persons that stand beside each other or two adjacent cars).
   That is due to the great masses of cosmic objects compared to those of ordinary objects on the Earth where the gravitational force is directly proportional to the product of the attracted masses.

Example 1

Find the mutual attraction force between the Sun and Jupiter given that the mass of the Sun is 2×10^{30} kg, the mass of Jupiter is 1.89×10^{27} kg and the distance between their centers is 7.73×10^{11} m. (knowing that : $G = 6.67 \times 10^{-11} N.m^2/kg^2$)



Solution

$M = 2 \times 10^{30}$ kg $m = 1.89 \times 10^{27}$ kg

$r = 7.73 \times 10^{11}$ m $G = 6.67 \times 10^{-11}$ N.m^2/kg^2

$F = ?$

$$F = G\frac{Mm}{r^2}$$

$$= 6.67 \times 10^{-11} \times \frac{1.89 \times 10^{27} \times 2 \times 10^{30}}{(7.73 \times 10^{11})^2} = 4.22 \times 10^{23}\ \text{N}$$

This force keeps Jupiter orbiting the Sun.

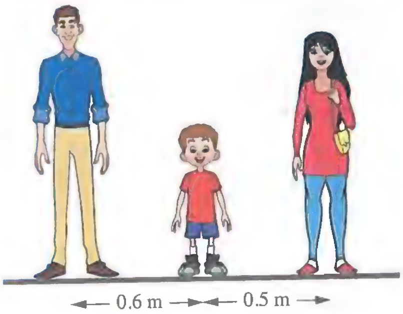
Example 2

A child walks with his parents as in the opposite figure. If the masses of the child, his mother and his father are 30 kg, 65 kg and 80 kg respectively, calculate the mutual attraction force between each of the following by showing the effect of these forces on the child's motion path :

(a) The child and his mother.

(b) The child and his father.

(knowing that : $G = 6.67 \times 10^{-11}$ N.m^2/kg^2)



Solution

$m_1 = 30$ kg $m_2 = 65$ kg $m_3 = 80$ kg $r_{12} = 0.5$ m $r_{13} = 0.6$ m

$G = 6.67 \times 10^{-11}$ N.m^2/kg^2 $F_{12} = ?$ $F_{13} = ?$

(a) $$F_{12} = \frac{Gm_1m_2}{r_{12}^2} = \frac{6.67 \times 10^{-11} \times 30 \times 65}{(0.5)^2} = 5.2 \times 10^{-7}\ \text{N}$$

(b) $$F_{13} = \frac{Gm_1m_3}{r_{13}^2}$$

$$= \frac{6.67 \times 10^{-11} \times 30 \times 80}{(0.6)^2} = 4.45 \times 10^{-7}\ \text{N}$$

The mutual attraction force between the child and each one of his parents is very small, so we don't notice it or feel it and it doesn't affect the path of the child.

Example 3

Calculate the attraction force between the Earth and a satellite of mass 2000 kg, if it rotates around the Earth at a height that equals the radius of the Earth.
(knowing that : the radius of the Earth = 6380 km, the mass of the Earth = 5.98×10^{24} kg and the gravitational constant = 6.67×10^{-11} N.m^2/kg^2)

Solution

$m = 2000$ kg $R = 6380$ km $M = 5.98 \times 10^{24}$ kg

$G = 6.67 \times 10^{-11}$ N.m^2/kg^2 $F = ?$

Clue

$\because$ *The satellite rotates around the Earth at a height that equals the radius of the Earth (R).*

$\therefore r = 2R$

$$F = \frac{GmM}{r^2} = \frac{6.67 \times 10^{-11} \times 2000 \times 5.98 \times 10^{24}}{(2 \times 6380 \times 10^3)^2} = 4.9 \times 10^3 \text{ N}$$

Distinguished Scientists

Abu Al-Reihan Al Biruni :

The astronomer Abu Al-Reihan Al Biruni succeeded to determine the perimeter of the Earth.

Other Arab scientists like Ali Ben Eissa Osterlab and Ali Al-Buhtury had contributions in the development of astronomy.

Test yourself

Answered

1. **Which of them** acts with larger gravitational force on the other (the Earth or the Moon) ? **And Why** ?

....
....
....

2. **Choose :** Two moons A and B that have equal masses are rotating around a planet. If the radii of their orbitals are r and 2r respectively, then the attraction force of the planet with the moon B is .... its attraction force with the moon A.

(a) 4 times (b) equal to (c) half (d) quarter

QUESTIONS ON
Chapter 2
LESSON ONE

Universal Gravitational Force

Interactive test

First Multiple choice questions

1 If the distance between the centers of two bodies is doubled and their masses are kept unchanged, the mutual attraction force between them will be ....

ⓐ doubled ⓑ halved ⓒ quartered ⓓ increases 4 times

2 If the distance between the centers of two masses decreased to its half, the mutual attraction force between them ....

ⓐ is doubled ⓑ increases 4 times
ⓒ decreases to its half ⓓ does not change

3 Two similar balls each of mass (m) and radius (r), placed in contact to each other, then the mutual attraction force between them is given by the relation ....

ⓐ $F = \frac{Gm^2}{r^2}$ ⓑ $F = \frac{Gm^2}{4\,r^2}$ ⓒ $F = \frac{2\,Gm}{r^2}$ ⓓ $F = \frac{Gm^2}{2\,r^2}$

4 Two balls of masses 8 kg and 20 kg , the distance between their centers is 0.2 m, if the universal gravitational constant is G, so the gravitational force between them in newton = ...

ⓐ 8000 G ⓑ 4000 G ⓒ 40 G ⓓ 8 G

5 If the distance between the centers of two identical balls is 1 m and the gravitational force between them is 1 N, the mass of each one of them equals ....
$(G = 6.67 \times 10^{-11}\ N.m^2/kg^2)$

ⓐ 1 kg ⓑ 1.22×10^5 kg ⓒ 2×10^5 kg ⓓ 0.1 kg

6 If the gravitational acceleration due to gravity on the Moon's surface is $\frac{1}{6}$ that on the Earth's surface, then the ratio between the universal gravitational constant on the Earth's surface to that on the Moon's surface is ....

ⓐ $\frac{1}{6}$ ⓑ $\frac{1}{3}$ ⓒ $\frac{1}{1}$ ⓓ $\frac{6}{1}$

7 Two bodies of mass (m_1) and (m_2) and the distance between them is (r). If the mass of the first body is doubled and the distance between them is also doubled, the gravitational force between them ....

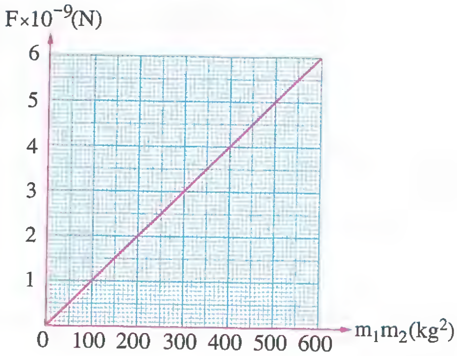
ⓐ does not change ⓑ is doubled
ⓒ decreases to its half ⓓ becomes 4 times its value

8 The measuring unit of the general gravitational constant is .... **(Choose two answers)**

ⓐ N.m.kg ⓑ $N.m^2/kg^2$ ⓒ $N.m^2$ ⓓ $m^3.kg/s^2$ ⓔ $m^3/kg.s^2$

---

9 The opposite graph represents the relation between the product of the masses of two bodies (m_1m_2) and the gravitational force between them (F), so the distance between the two bodies (r) equals ....
($G = 6.67 \times 10^{-11}$ $N.m^2/kg^2$)



ⓐ 1.84 m ⓑ 2.58 m

ⓒ 4.62 m ⓓ 5.78 m

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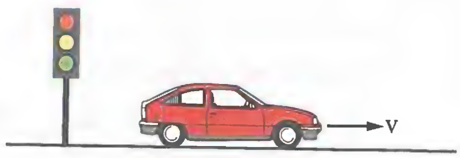
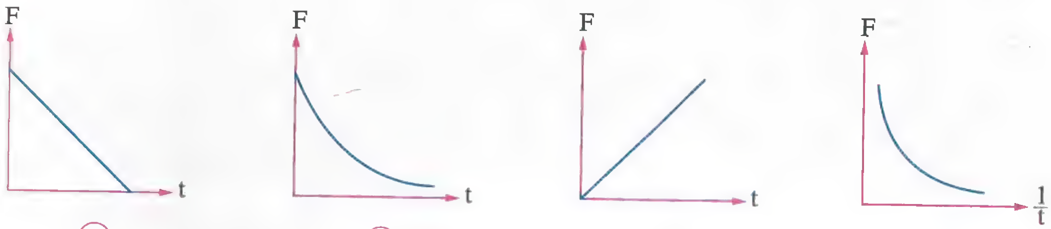
10 In the opposite figure : If the car is moving with uniform velocity away from the traffic lights, then what is the best graphical representation that represents the change of the gravitational force (F) between the car and the traffic lights with the time (t) is ....





ⓐ ⓑ ⓒ ⓓ

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11 Two asteroids, one with a mass of 7.12×10^{18} kg and the other with mass 5.33×10^{8} kg and the distance between them is 10×10^{10} m. What is the gravitational force on the larger asteroid ? ....

ⓐ 4.61×10^{-10} N ⓑ 4.74×10^{-6} N

ⓒ 2.53×10^{-5} N ⓓ 3.55×10^{-6} N

---

12 A satellite orbits the Earth at a distance of 100 km. The mass of the satellite is 100 kg while the mass of the Earth is approximately 6×10^{24} kg and the radius of the Earth is approximately 6.4×10^{6} m. What is the approximate gravitational force that acts on the satellite ? ....

ⓐ 4×10^{4} N ⓑ 6.2×10^{6} N

ⓒ 4×10^{8} N ⓓ 9.5×10^{2} N

13. Two satellites of equal masses orbit a planet. Satellite B orbits at twice the orbital radius of satellite A. Which of the following statements is true ? ....

ⓐ The gravitational force on satellite A is four times that on satellite B
ⓑ The gravitational force on satellite A is two times that on satellite B
ⓒ The gravitational force on the two satellites is equal
ⓓ The gravitational force on satellite A is four times that on satellite B

14. A 70 kg astronaut floats at a distance of 10 m from a 50000 kg spacecraft. What is the force of attraction between the astronaut and spacecraft ? ....

ⓐ 2.4×10^{-6} N ⓑ 2.4×10^{-5} N
ⓒ Zero; there is no gravity in space ⓓ 2.4×10^{5} N

15. Two masses, m_1 and m_2 are separated by a distance d. What changes in the variables will result in no change in the gravitational force between the two masses ? ....

(Choose two answers)

ⓐ m_1 is doubled and d is doubled
ⓑ m_2 is tripled and d is quadrupled
ⓒ Both m_1 and m_2 are tripled and d is tripled
ⓓ m_2 is quadrupled and d is doubled

16. A block with a mass of 30 kg is hanging still from a string. If you place another block with a mass of 10 kg at a distance of 2 m away, what is the gravitational force between the two blocks ? ....

ⓐ 1×10^{-11} N ⓑ 5×10^{-10} N ⓒ 1×10^{-10} N ⓓ 5×10^{-9} N

17. Mars orbits the Sun at a distance of 2.3×10^{11} m. The mass of the Sun is 2×10^{30} kg and the mass of Mars is 6.4×10^{23} kg. Approximately what is the gravitational force that the Sun exerts on Mars ? ....

ⓐ 1.6×10^{20} N ⓑ 1.6×10^{21} N ⓒ 3.7×10^{21} N ⓓ 3.7×10^{32} N

18. The Moon has a mass of 7.4×10^{22} kg and a radius of 1.7×10^{6} m. What is the gravitational force experienced by a 70 kg astronaut standing on the lunar surface ? ....

ⓐ 10 N ⓑ 50 N ⓒ 100 N ⓓ 120 N

19. The planet Jupiter orbits the Sun at a nearly constant speed. Which of the following statements are true ? .... **(Choose two answers)**

ⓐ There is a force on Jupiter towards the center of the orbit
ⓑ There is a force on Jupiter pulling it out from the center of the orbit
ⓒ There is a force on Jupiter in the direction of its motion
ⓓ Jupiter is accelerating towards the center of the orbit

20 Four planets A , B, C and D orbit the same star. The relative masses and distances from the star for each planet are shown in the table. For example, planet A has twice the mass of planet B and planet D has three times the orbital radius of planet A. Which planet has the highest gravitational attraction to the star ? ....

Planet	Relative mass	Relative distance
A	2 m	r
B	m	0.1 r
C	0.5 m	2 r
D	4 m	3 r

ⓐ Planet A ⓑ Planet B ⓒ Planet C ⓓ Planet D

Second Essay questions

1 **Explain each of the following statements :**

(1) The gravitational attraction is obvious among orbs.

(2) The attraction force between two men at a distance of a few meters between each other cannot be detected.

(3) The attraction force between two masses increases 4 times as the distance between them is halved.

2 **What are the factors affecting** the attraction force between two bodies ? **Mention the law and the relation of proportionality**.

3 **Complete the diagram :**

(a) ..... force ← Originated from ← **Circular motion in the universe** → belongs to → ..... (b) ..... law

Circular motion in the universe → Examples:

- Motion of Earth around the Sun
- ..... (c) .....
- ..... (d) .....

Third Problems

1 **Calculate the attraction force between the Sun and Jupiter planet, knowing that :**

- Universal gravitational constant = 6.67×10^{-11} N.m^2/kg^2
- Mass of the Sun = 1.989×10^{30} kg

- Mass of Jupiter = 1.898×10^{27} kg
- The mean orbital radius of Jupiter around the Sun = 7.786×10^{11} m *(4.15×10^{23} N)*

2. Two balls having the same mass and the distance between their centers is 2 m and the attraction force between them is 6.67×10^{-9} N. **calculate** the mass of each ball. *(20 kg)*

3. Two bodies of masses 2 kg , 8 kg are separated by a distance of 20 cm, if the universal gravitational constant is 6.67×10^{-11} N.m^2/kg^2 , **calculate** the gravitational force between them. *(2.67×10^{-8} N)*

4. A 3 kg mass is located 10 cm away from a 6 kg mass. **What** is the resultant gravitational force on a 2 kg mass located at the midpoint of a line joining the first two masses ? (assuming that the masses behave as point masses) *(1.6×10^{-7} N)*

5. The center of the Moon is 3.9×10^5 km away from the center of the Earth. The mass of the Moon is 7.3×10^{22} kg and the mass of the Earth is 6×10^{24} kg. **How far** from the Earth's center an object is existed if the gravitational forces of the Earth and the Moon on the object are equal and opposite ?
(assume the object is on the line connecting the Earth and the Moon) *(3.5×10^5 km)*

6. If the relation between the mass of an object (m) that is placed on a planet and the attraction force (F) between it and the planet is given in the table where the planet's mass is 5.9×10^{24} kg :

F (N)	40	80	120	160	a	240	280
m (kg)	5	10	15	20	25	30	b

(a) **Draw a relation between** (F) on the y-axis and (m) on the x-axis.

(b) **From the graph find :**

1- The values of a and b.

2- The radius of the planet.

(knowing that : $G = 6.67 \times 10^{-11}$ N.m^2/kg^2) *(200 N, 35 kg, 7013.6 km)*

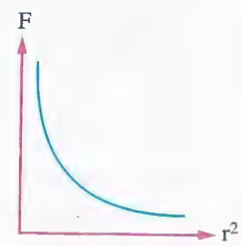
Chapter 2

LESSON TWO

Gravitational Field

The gravitational field

- The universal gravitational law states that the gravitational attraction between two bodies is inversely proportional to square the distance between their centers. Thus, the gravitational force decreases gradually as the distance increases till the distance between the centers of the two bodies reaches a point at which the attraction ceases.



- Within this distance, there is a region in which the gravitational forces appear, this region is called **the gravitational field**.

Deducing the gravitational field intensity (g)

- By assuming that a body of mass 1 kg is placed in the Earth's gravitational field and at a distance r from the center of the Earth, then the attraction force of the Earth to the body :

$$F = mg = 1 \times g = g \quad (1)$$

And by applying the universal gravitational law :

$$F = G\frac{mM}{r^2} = \frac{GM}{r^2} \quad (2)$$

From (1) and (2) : $g = \frac{GM}{r^2}$

Where : (M) is the mass of the Earth (5.98×10^{24} kg)

If the body is at :

▶ The Earth's surface.	▶ A height (h) above the Earth's surface.	▶ A depth (h) below the Earth's surface.
then		
$g = \frac{GM}{R^2}$	$g = \frac{GM}{(R+h)^2}$	$g = \frac{GM}{(R-h)^2}$

Where : (R) is the radius of the Earth (6378 km approximately)

- From the previous we notice that the **gravitational field intensity** at a certain point equals numerically the acceleration due to gravity of the Earth at this point.

The gravitational field intensity :

It is the gravitational force acting on a mass of 1 kg at a certain point.

- To compare the acceleration due gravity for two planets : $\frac{g_1}{g_2} = \frac{M_1 R_2^2}{M_2 R_1^2}$

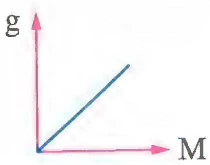
Note :

The gravitational field intensity varies slightly at Earth's surface because of the variation of the Earth's radius from one position to another where the Earth is not perfectly spherical but it is an oblate spheroid (a sphere that is squashed at its poles and swollen at the equator) and that is due to the centripetal force that originates from the rotation of the Earth around itself.

The factors that affect gravitational field intensity (g) at a point :

1 The mass of planet :

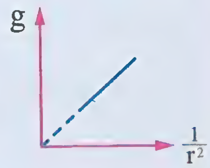
The gravitational field intensity is directly proportional to the mass of the planet when the distance between the point and the center of the planet is constant.



Slope $= \frac{\Delta g}{\Delta M} = \frac{G}{r^2}$

2 The distance from the center of the planet :

The gravitational field intensity is inversely proportional to square the distance from the center of the planet.



Slope $= \frac{\Delta g}{\Delta\left(\frac{1}{r^2}\right)} = GM$

$$g = \frac{GM}{r^2}$$

Example 1

A satellite of mass 10^4 kg orbits the Earth at a height of 600 km from its surface, calculate :

(a) The acceleration due to gravity of the Earth that affects the satellite on its orbit.

(b) The weight of the satellite in its orbit.

(knowing that : $R = 6378$ km, $M = 5.98 \times 10^{24}$ kg, $G = 6.67 \times 10^{-11}$ N.m²/kg²)

Solution

$m = 10^4$ kg | $h = 600$ km | $R = 6378$ km | $M = 5.98 \times 10^{24}$ kg

$G = 6.67 \times 10^{-11}\ N.m^2/kg^2$ | $g = ?$ | $w = ?$

(a) $$g = \frac{GM}{r^2} = \frac{GM}{(R+h)^2} = \frac{6.67 \times 10^{-11} \times 5.98 \times 10^{24}}{((6378 + 600) \times 10^3)^2} = 8.19\ m/s^2$$

(b) $w = mg = 8.19 \times 10^4$ N

Example 2

A planet has a mass twice that of Earth and a diameter twice that of Earth.
Find the ratio between the acceleration due gravity on the planet and the acceleration due to gravity on Earth.

Solution

$M_p = 2\,M_e$ | $R_p = 2\,R_e$ | $\frac{g_p}{g_e} = ?$

$$\frac{g_p}{g_e} = \frac{M_p R_e^2}{M_e R_p^2} = \frac{2M_e R_e^2}{M_e \times 4R_e^2} = \frac{1}{2}$$

Test yourself

Answered

A satellite orbits the Earth at a height h from its surface.
If the acceleration due to gravity of the Earth at the satellite's orbit is half its value on the Earth's surface,
Calculate the height of the satellite from the Earth's surface (h) in terms of the radius of Earth (R).

....

....

....

....

Practical Experiment

Measuring the mass of the Earth by knowing its radius

1. Experiment Objective :

Calculating the mass of the Earth by knowing its radius.

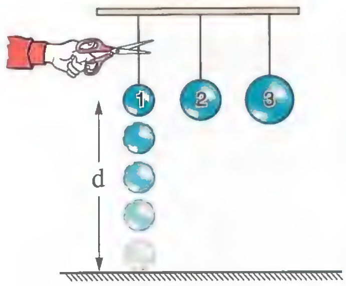
2. Experiment Idea :

- Finding the acceleration due gravity using the second law of motion : $g = \frac{2d}{t^2}$
  , where (d) is the height from which an object falls to the ground during time (t).
- Finding the mass of the Earth using the relation : $g = \frac{GM}{r^2}$
  , where (G) is the gravitational constant, (M) is the mass of the Earth and (r) is the distance away from the Earth's center which is nearly equal to the radius of Earth (R).

3. Tools :

- Three pendulums of different masses.
- Meter tape.
- Stopwatch.
- Scissors.

4. Procedure :



1. Hang the three pendulums so that the distance between the center of each pendulum ball and the ground (d) is equal.
2. Cut the string at the hanging point of the first pendulum and record the time (t) taken to reach the ground.
3. Repeat the previous step for the other two pendulums.
4. Record the results obtained in the following table :

Ball	Height (d)	Time (t)	Gravitational field intensity ($g = \frac{2d}{t^2}$)
First ball			
Second ball			
Third ball			

5. Calculate the average of the gravitational field intensity (g).
6. By knowing the gravitational field intensity (g), the radius of the Earth ($R = 6.38 \times 10^6$ m) and the universal gravitational constant ($G = 6.67 \times 10^{-11}$ $N.m^2.kg^{-2}$).

   Calculate the mass of the Earth using the relation : $g = \frac{GM}{r^2}$

QUESTIONS ON

Chapter 2

LESSON TWO

Gravitational Field

Interactive test

First Multiple choice questions

1 The acceleration due to Earth's gravity .... **(Choose two answers)**

(a) is a general universal constant
(b) changes according to the height from the Earth's surface
(c) changes through the seasons of the year
(d) varies according to the distance between Earth and Sun
(e) doesn't change by changing the mass of the body

2 A planet of mass 5.98×10^{24} kg and radius 6378 km. If $G = 6.67 \times 10^{-11}$ $N.m^2/kg^2$, so the intensity of the planet's gravitational field at a point that lies at a distance 36000 km from its surface equals .... N/kg.

(a) 22.2×10^4 (b) 22.2×10^2 (c) 22.2×10^{-2} (d) 22.2×10^{-4}

3 On the scale of a building, gravitational field is ....

(a) increasing (b) decreasing (c) uniform (d) varying

4 Which of the following affect the strength of the gravitational field on the surface of a planet ? .... (more than one answer is correct)

(a) The mass of the object at the surface
(b) The mass of the planet
(c) The radius of the planet
(d) The presence of air at the surface of the planet

5 Assign the acceleration of the Moon the symbol a_m and the mass of the Moon M_m. If a satellite with a mass M_s was placed in the same orbit of the Moon at the same speed, what is the gravitational field strength at the satellite's orbit ? ....

(a) a_m (b) $(M_s/M_m)\ a_m$ (c) $(M_m/M_s)\ a_m$ (d) $(M_s + M_m)\ a_m/M_s$

6 The mass of Mercury is 3.3×10^{23} kg and its radius is 2.439×10^6 m. If a body of mass 65 kg is placed on Mercury's surface , then .... **(Choose two answers)**

(knowing that : the acceleration due to gravity on Earth's surface is 9.8 m/s^2 and the general gravitational constant is 6.67×10^{-11} $N.m^2/kg^2$)

(a) the weight of the body on Mercury's surface is 240.5 N
(b) the weight of the body on Mercury's surface is 637 N
(c) the weight of the body on Mercury's surface is 320.5 N
(d) the mass of the body on Earth's surface is 65 kg
(e) the mass of the body on Earth's surface is 172 kg

7. If the acceleration due to gravity of the Earth at the orbit of a satellite that orbits the Earth is 2.5 m/s^2, then the distance between the satellite and the Earth's surface (h) equals .... (where : R is the radius of the Earth and the acceleration due to gravity at the Earth's surface = 10 m/s^2)

ⓐ 2 R ⓑ R ⓒ $\frac{R}{2.5}$ ⓓ $\frac{R}{4}$

8. If R is the radius of the Earth, so the height at which the weight of a body becomes $\frac{1}{4}$ its weight on the surface of the Earth is ....

ⓐ 2 R ⓑ R ⓒ $\frac{R}{2}$ ⓓ $\frac{R}{4}$

9. At a place, value of (g) is less by 1 % than its value on the surface of the Earth (radius of Earth (R) = 6400 km). The place is ....

ⓐ 64 km below the surface of the Earth
ⓑ 64 km above the surface of the Earth
ⓒ 30 km below the surface of the Earth
ⓓ 32 km above the surface of the Earth

10. An object has a mass of 50 kg and a weight of 500 N when it is resting on the surface of the Earth. If it is moved to a height equal to three times the Earth's radius, what is the object's new weight ? ....

ⓐ 300 N ⓑ 31.25 N ⓒ 130 N ⓓ 60.5 N

11. Two asteroids in the space are close enough to each other. Each has a mass of 6.69×10^{15} kg. If they are 100000 m apart, what is the gravitational acceleration that they experience ? ....

ⓐ 3.89×10^{10} m/s^2
ⓑ 5.12×10^{4} m/s^2
ⓒ 2.99×10^{11} m/s^2
ⓓ 4.46×10^{-5} m/s^2

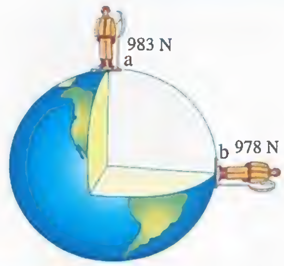
12. Two asteroids, one with a mass of 7.12×10^{18} kg and the other with a mass of 5.33×10^{8} kg and the distance between them is 10×10^{10} m. What is the acceleration of the smaller asteroid ? ....

ⓐ 3.79×10^{5} m/s^2
ⓑ 9.41×10^{-7} m/s^2
ⓒ 4.75×10^{-14} m/s^2
ⓓ 6.11×10^{-24} m/s^2

13. When climbing from the sea level to the top of mount Everest, a hiker changes elevation by 8848 m. By what percentage will the gravitational field of the Earth change during the climb ? .... (where the Earth's mass is 6×10^{24} kg and its radius is 6.4×10^{6} m)

ⓐ It will increase by approximately 0.3 %
ⓑ It will decrease by approximately 0.3 %
ⓒ It will increase by approximately 12 %
ⓓ It will decrease by approximately 12 %

Second Essay questions



1. In the opposite figure, **explain why** is the weight of the man at the points a and b different ?

2. Imagine that the Earth starts to shrink uniformly while its mass remains constant. **What would happen to** the value of the acceleration due to gravity on its surface ?

3. **When** the gravitational field intensity and the acting force equalize ?

4. **What are the factors on which each of the following depends ? Mention the law and the relation of proportionality.**
   (a) The acceleration due to gravity on a planet.
   (b) The gravitational field intensity of the Earth.

5. **What** is the difference between the gravitational field and the gravitational field intensity ?

Third Problems

1. If the radius of a planet is 7.14×10^7 m and its mass is 1.9×10^{27} kg and $G = 6.67 \times 10^{-11}$ N.m^2/kg^2, **find :**
   (a) The attraction force acting on an object of mass 1 kg at the planet's surface.
   (b) The acceleration due to gravity on the planet's surface. *(24.86 N, 24.86 m/s^2)*

2. **Calculate the mass of Earth, knowing that :**
   - Acceleration due to gravity on Earth = 9.8 m/s^2
   - $G = 6.67 \times 10^{-11}$ N.m^2/kg^2
   - Radius of Earth = 6.36×10^6 m *(5.94×10^{24} kg)*

3. If the mass of the planet Mercury is 3.3×10^{23} kg and its radius is 2.439×10^6 m , **what** is the weight of a body of mass 65 kg on Mercury and **what** is the weight of the same object on the Earth (knowing that : $G = 6.67 \times 10^{-11}$ N.m^2/kg^2) ?
   (240.5 N, 637 N)

4. On a distant planet, the acceleration due to gravity is 5 m/s^2 and the radius of the planet is roughly 4560 km. **Use the law of gravitation to estimate** the mass of this planet.
   (1.56×10^{24} kg)

5. **Calculate** the ratio between the acceleration due to gravity on the Moon and that on the Earth, knowing that :
   - Mass of Earth 5.976×10^{24} kg and its radius 6.4×10^{6} m.
   - Mass of Moon 7.35×10^{22} kg and its radius 1.74×10^{6} m. *(0.1664)*

6. A planet of mass 5 times the mass of the Earth and its diameter 5 times that of the Earth. **Calculate** the ratio of the acceleration due to gravity on Earth's surface to that on the planet. *($\frac{5}{1}$)*

7. A planet of mass 4 times that of the Earth and its diameter is double that of the Earth. **Calculate** the weight of an object on its surface if its weight on the Earth is 150 N. *(150 N)*

8. A body of weight 45 N is placed at the Earth's surface, **calculate** its weight at a height that equals the quarter of Earth's diameter. (where : the mass of Earth = 5.98×10^{24} kg, the acceleration due to gravity at the surface of the Earth = 9.8 m/s^2, the universal gravitational constant = 6.67×10^{-11} N.m^2/kg^2) *(20 N)*

9. An object is dropped with no initial velocity, above the surface of planet Big Alpha and falls 13.5 meters in 3 seconds, the radius of planet Big Alpha is 5.82×10^{6} meters.
   (a) **What** is the acceleration of the falling object.
   (b) **What** is the mass of planet Big Alpha. *(3 m/s^2 , 1.52×10^{24} kg)*

10. The mass of the Earth is about 81 times the mass of the Moon. If the radius of the Earth is four times that of the Moon, **what** is the acceleration due to gravity on the Moon ? *($\approx \frac{1}{5} g_e$)*

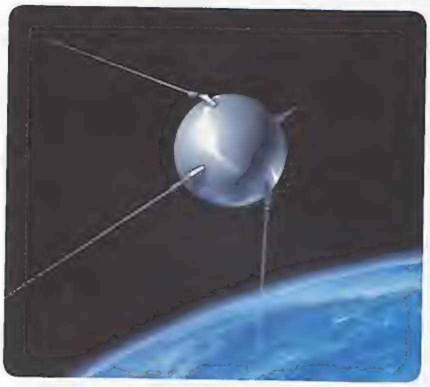
11. A planet has the same mass as that of the Earth but its diameter twice that of the Earth. **Calculate** the weight of an object on the planet if its weight on the Earth is 100 N. *(25 N)*

Chapter 2

LESSON THREE

Satellites

- Man has dreamed for centuries to explore the space and to achieve that dream, he continued developing probes and rockets that launch space ships to orbit the Earth or reach further to another planet like Mars. That dream has come true on the 4^{th} of October 1957 when the first satellite (Sputnik) has been sent into space.



- That was followed by sending other satellites and stepping onto the Moon and space exploration is still in continuous progress.

The idea of launching a satellite

A satellite in its orbit is considered as an object that falls freely towards the Earth's surface (because it is under the effect of Earth's gravity), in spite of this it never reaches the Earth's surface. Isaac Newton explained this where he imagines that when projecting a cannon projectile from the top of a mountain in a horizontal direction (neglecting the air resistance) :

- The projectile moves through a certain horizontal distance before falling freely on the ground where it moves in a curved path towards the Earth.

- By increasing the velocity of projection, the horizontal distance moved by the projectile before falling on the ground increases where it moves in a less curved path.

- At a certain projecting velocity, where **the curvature of the projectile path equalize with the curvature of the Earth's surface**, the projectile orbits the Earth in a constant roughly circular path and it becomes a follower for the Earth like the Moon and it is named a **satellite** and this velocity is called the **orbital velocity of the satellite**.

The orbital velocity of a satellite :

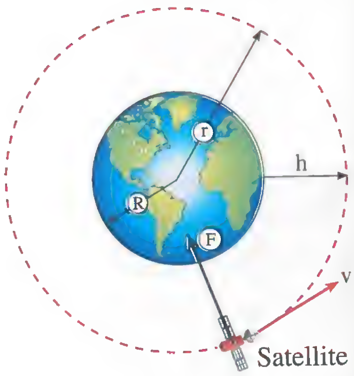
It is the velocity that makes the satellite orbit the Earth in a roughly circular path where its distance from the Earth's surface is kept constant.

Deducing the orbital velocity of a satellite (v)

Proof

- Assume that a satellite of mass (m) moves with a velocity (v) in an orbit of radius (r) around the Earth of mass (M) as in figure :
  - The force of attraction between the Earth and the satellite is given by the relation : $F = G\frac{mM}{r^2}$
  - The force of attraction between the Earth and the satellite is normal to the direction of the motion of the satellite so it makes the satellite move in a circular path : $F = \frac{mv^2}{r}$

  So the attraction force between the Earth and the satellite is the same centripetal force that acts on the satellite.



$$\therefore G\frac{mM}{r^2} = \frac{mv^2}{r} \qquad \therefore v^2 = \frac{GM}{r}$$

$$\therefore \boxed{v = \sqrt{\frac{GM}{r}}}$$

Where (G) is the gravitational constant and if the height that the satellite was launched to is (h) and the radius of the Earth is (R), then : $r = R + h$

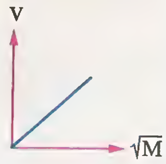
$$\therefore \boxed{v = \sqrt{\frac{GM}{R+h}}}$$

The factors that affect the orbital velocity of a satellite :

1 The mass of the planet :

The orbital velocity of a satellite is directly proportional to the square root of the mass of the planet at constant radius of the orbit.

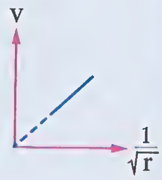
$$\text{Slope} = \frac{\Delta v}{\Delta\sqrt{M}} = \sqrt{\frac{G}{r}}$$



2 The radius of the orbit :

The orbital velocity of a satellite is inversely proportional to the square root of the radius of the orbit.

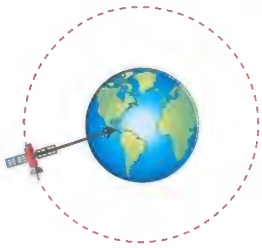
$$\text{Slope} = \frac{\Delta v}{\Delta\left(\frac{1}{\sqrt{r}}\right)} = \sqrt{GM}$$



$$v = \sqrt{\frac{GM}{r}}$$

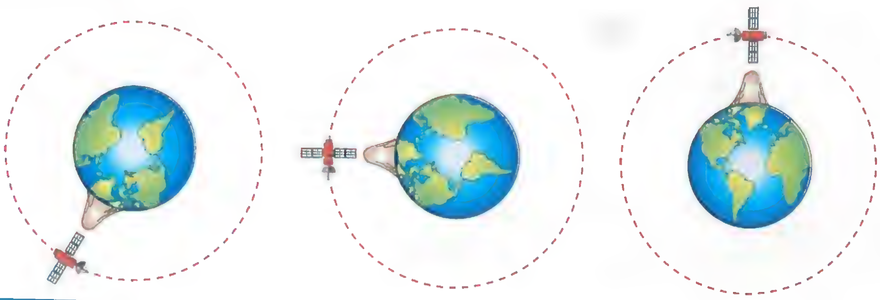
Notes :

1. If we imagine that a satellite stopped suddenly while rotating around the Earth (its velocity became zero), so the satellite will move in a straight line towards the Earth under the effect of the Earth's gravity and falls down on its surface.



2. If we imagine that the gravitational force between the Earth and a satellite vanished, so the satellite will move in a straight line tangent to the circular path away from the Earth.

3. The satellite that is synchronized with the rotation of the Earth (follows the Earth) has a periodic time that is equal to the periodic time of the Earth's rotation around itself during one solar day (24 hours), so the satellite remains above a constant point on the Earth's surface.



4. We can calculate the time taken by the satellite to complete one revolution around the Earth (the periodic time T) from the relation :

$$T = \frac{\text{Circumference}}{\text{Speed}} = \frac{2\pi r}{v}$$

5. We can deduce the relation between the radius (r) of the orbit of a satellite that orbits a planet and the periodic time of its motion (T) as follows :

$$\because v = \sqrt{\frac{GM}{r}} = \frac{2\pi r}{T} \qquad \therefore \frac{GM}{r} = \frac{4\pi^2 r^2}{T^2}$$

$$\therefore T^2 = \frac{4\pi^2 r^3}{GM} \qquad \therefore \boxed{T^2 \propto r^3}$$

6. The orbital velocity of a satellite that orbits the Earth is inversely proportional to the square root of the radius of the orbit according to the relation $\left(v = \sqrt{\frac{GM}{r}}\right)$ and **we can't say that the orbital velocity :**

- is directly proportional to the radius of the orbit from the relation $\left(v = \frac{2\pi r}{T}\right)$ because the periodic time also depends on the radius of the orbit from the relation $\left(T^2 = \frac{4\pi^2 r^3}{GM}\right)$.
- is directly proportional to the square root of the radius of the orbit according to the relation $(v = \sqrt{gr})$ because the gravitational field intensity also depends on the radius of the orbit from the relation $\left(g = \frac{GM}{r^2}\right)$.

Example 1

The Moon rotates around the Earth in a circular orbit of radius 3.85×10^5 km and completes one revolution in 27.3 days. Calculate the mass of the Earth.
(knowing that : Universal gravitation constant $= 6.67 \times 10^{-11}\ m^3.kg^{-1}.s^{-2}$, $\pi = 3.14$)

Solution

T = 27.3 days | $G = 6.67 \times 10^{-11}\ m^3.kg^{-1}.s^{-2}$ | $r = 3.85 \times 10^5$ km | M = ?

$$T = 27.3 \times 24 \times 60 \times 60 = 2.36 \times 10^6\ s$$

$$, v = \frac{2\pi r}{T} = \frac{2 \times 3.14 \times 3.85 \times 10^5 \times 10^3}{2.36 \times 10^6} = 1024.49\ m/s$$

$$v^2 = \frac{GM}{r}$$

$$M = \frac{v^2 \times r}{G} = \frac{(1024.49)^2 \times 3.85 \times 10^5 \times 10^3}{6.67 \times 10^{-11}} = 6.06 \times 10^{24}\ kg$$

Example 2

A satellite rotates around the Earth in a roughly circular orbit at a height of 940 km above the Earth's surface. Calculate the orbital velocity and the time required by the satellite to make a complete revolution around the Earth.
(knowing that : $R = 6360$ km, $M = 6 \times 10^{24}$ kg , $G = 6.67 \times 10^{-11}$ N.m²/kg², $\pi = 3.14$)

Solution

$h = 940$ km | $R = 6360$ km | $M = 6 \times 10^{24}$ kg | $G = 6.67 \times 10^{-11}$ N.m^2/kg^2

$v = ?$ | $T = ?$

$r = R + h = 6360 + 940 = 7300 \text{ km} = 7.3 \times 10^6 \text{ m}$

$$v = \sqrt{\frac{GM}{r}} = \sqrt{6.67 \times 10^{-11} \times \frac{6 \times 10^{24}}{7.3 \times 10^6}} = 7.4 \times 10^3 \text{ m/s}$$

$$T = \frac{2\pi r}{v} = \frac{2 \times 3.14 \times 7.3 \times 10^6}{7.4 \times 10^3} = 6195.14 \text{ s} = 1.72 \text{ h}$$

Example 3

A satellite completes a revolution around the Earth in 94.4 minutes. If the length of its orbit = 43120 km, calculate the orbital velocity and the height of the satellite above the surface of the Earth. (knowing that : $R = 6360$ km)

Solution

$T = 94.4$ minutes | $R = 6360$ km | $2\pi r = 43120 \times 10^3$ m | $v = ?$ | $h = ?$

$$v = \frac{2\pi r}{T} = \frac{43120 \times 10^3}{94.4 \times 60} = 7613 \text{ m/s}$$

$$r = \frac{43120 \times 10^3}{2\pi} = 6.866 \times 10^6 \text{ m} = 6866 \text{ km}$$

$h = r - R = 6866 - 6360 = 506$ km

Example 4

Calculate the radius of the orbit of a satellite that is synchronized with the Earth (follows the Earth). (knowing that : $M = 5.98 \times 10^{24}$ kg , $G = 6.67 \times 10^{-11}$ N.m²/kg²)

Solution

$\boxed{T = 24\ h}$ $\boxed{M = 5.98 \times 10^{24}\ kg}$ $\boxed{G = 6.67 \times 10^{-11}\ N.m^2/kg^2}$ $\boxed{r = ?}$

$\because v = \sqrt{\frac{GM}{r}} = \frac{2\pi r}{T}$ $\quad\quad \therefore \frac{GM}{r} = \frac{4\pi^2 r^2}{T^2}$

$\therefore r^3 = \frac{GMT^2}{4\pi^2}$

$\therefore r = \sqrt[3]{\frac{GMT^2}{4\pi^2}}$

$= \sqrt[3]{\frac{6.67 \times 10^{-11} \times 5.98 \times 10^{24} \times (24 \times 60 \times 60)^2}{4 \times \left(\frac{22}{7}\right)^2}} = 4.22 \times 10^7\ m$

Enrichment information

As the mass of the satellite increases, a rocket of greater thrust is required to launch it into space and to acquire the required velocity to orbit the Earth.

Test yourself

Answered

Choose : A satellite orbits the Earth in a constant orbit. If a part that represents quarter the mass of the satellite separates from the satellite, then the orbital velocity of the satellite ....

(a) decreases to quarter its original value

(b) increases four times

(c) increases by a quarter of its original value

(d) remains constant

The importance of satellites

- The satellite is considered as a very high tower that can be used in transmitting and receiving the wireless waves.

⊙ Satellites can be classified according to their applications into :

1. Communication satellites, used in :

- TV transmission.
- Phone calls.
- Locating sites through GPS.
- Radio transmission.
- Internet.
- Monitor regions using Google Earth.


Satellites are used in TV & radio transmission


GPS to determine location


Google maps are imaged by satellites

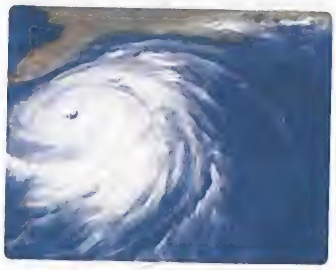
2. Astronomical satellites :

They are huge telescopes floating in the space.
They can be used to photograph the space accurately.


Astronomical satellites are huge telescopes

3. Remote sensing satellites, they are used to :

- Study and monitor the emigrant birds.
- Determine the mineral resources and their distributions underground.
- Look out for the agricultural yields to protect them against weather dangers.
- Study the formation of hurricanes.


Satellites are used in studying hurricanes

4. Explanatory and spying satellites :

They abound the information needed by military and political leaders to make decisions and war administration.


Satellites are used for spying and delivering information

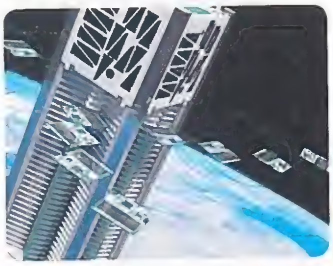
5. Weather satellites :

They are used to monitor weather and climate of the Earth by taking photographs for the atmosphere from a height of 35000 km from the surface.

They track hurricanes and monitor the atmospheric conditions like air quality, clouds and ice glaciers.

EKB

Chipsats



- There are millions of rocks that float in space and some of them may be dangerous for the Earth where they can destroy cities and kill thousands of people if they impact the Earth, so scientists have been concerned about tracking the rocks that may impact the Earth. Some scientists at NASA designed a model of a satellite smaller than a credit card to track these asteroids which is called **chipsat**.

- **Chipsats are made of a printed circuit board with installing the following components on it :**
  - A communication microchip as the one used in cell phones.
  - Solar cell to generate the energy in space.
  - An antenna to send signals to Earth.

- Chipsats are launched in space by using **cubic space ships** which is called kicksats, the kicksat is carrying about 130 chipsats. When a kicksat detects an approaching asteroid it launches the chipsats to spread around the asteroid and these chipsats move with the asteroid during its journey around the Sun.

- If the asteroid move away due to the gravity of the Moon or the Earth some of these chips break down or deflect away from the asteroid but the remaining chips will still working which make the losses acceptable because of the low cost of the chips where each one costs about 20 dollars so a lot of them can be launched at once to track the asteroids.

Satellites

Interactive test

First Multiple choice questions

1 The orbital velocity that is required to keep a satellite rotating around a planet depends on the .... **(Choose two answers)**

ⓐ mass of the satellite
ⓑ mass of the planet
ⓒ distance between the centers of the planet and the satellite
ⓓ periodic time of the satellite's rotation around the planet
ⓔ direction of the satellite's rotation around the planet

2 The orbital velocity of a satellite is inversely proportional to ....

ⓐ the mass of satellite
ⓑ the square root of its mass
ⓒ the radius of the orbit
ⓓ the square root of the orbital radius

3 Two satellites A and B rotate around the Earth. If the orbit radius of satellite A equals 4 times the orbit radius of satellite B. So, the ratio between the velocity of satellite A to that of satellite B equals ....

ⓐ 2 : 1　ⓑ 4 : 1　ⓒ 1 : 2　ⓓ 1 : 4

4 A satellite rotates at height 12000 km from a planet of mass 9.96×10^{22} kg. If the radius of the planet is 1063 km and $G = 6.67 \times 10^{-11}$ N.m^2/kg^2 so, the orbital velocity of the satellite = ... m/s

ⓐ 744　ⓑ 713.13　ⓒ 311　ⓓ 249.9

5 Two satellites having the same orbital radius, one rotates around the Earth and the other rotates around Mars. If the mass of Earth is nine times that of Mars, then the ratio between the linear speed (tangential) of the satellite rotating around the Earth to that rotating around Mars equals ....

ⓐ $\frac{1}{9}$　ⓑ $\frac{9}{1}$　ⓒ $\frac{1}{3}$　ⓓ $\frac{3}{1}$

6 A satellite orbits the Earth at a height (h) from the Earth's surface with an orbital velocity of $\frac{1}{2}\sqrt{\frac{GM}{R}}$ where R is the radius of the Earth, then the distance between the satellite and the surface of the Earth (h) is ....

ⓐ $\frac{1}{2}$ R　ⓑ 2 R　ⓒ 3 R　ⓓ 4 R

7 Two satellites S_1 and S_2 orbit the Earth at two different heights from the Earth's surface. If the ratio between their periodic times $(\frac{T_1}{T_2})$ is $\frac{8}{1}$, then the ratio between their orbital velocities $(\frac{v_1}{v_2})$ is ....

(a) $\frac{8}{1}$ (b) $\frac{1}{4}$ (c) $\frac{2}{1}$ (d) $\frac{1}{2}$

8 A satellite orbits the Earth at a distance of 200 km. If the mass of the Earth is 6×10^{24} kg and the Earth's radius is 6.4×10^6 m, what is the satellite's speed ? ....

(a) 1×10^3 m/s
(b) 3.5×10^3 m/s
(c) 7.8×10^3 m/s
(d) 5×10^6 m/s

9 Phobos, a moon of the planet Mars, whose orbital radius is 9380 km and its orbital period is 0.319 days (2.77×10^4 seconds). The mass of Mars based on this data is ....
(where : $G = 6.67 \times 10^{-11}$)

(a) 6.37×10^{23} kg
(b) 1.36×10^{15} kg
(c) 9.21×10^{34} kg
(d) 3.23×10^{27} kg

10 The orbital radius of two satellites rotating around a planet are 2×10^6 m and 1×10^6 m respectively. If the periodic time of the second satellite is 8×10^7 s, then the periodic time of the first equals ....

(a) 5×10^5 s
(b) 4×10^6 s
(c) 2.3×10^8 s
(d) 4.5×10^8 s

11 Two satellites are at the same distance from the Earth. If one of the satellites has a mass of m and the other has a mass of 2 m, which one will have the smaller acceleration ? ....

(a) m
(b) 2 m
(c) They both will have the same acceleration
(d) Neither will have an acceleration

Second Essay questions

1 **Explain the following statements :**

(1) The orbital velocity of a satellite depends on its orbital radius only.

(2) The orbital velocity of a satellite of mass 5×10^3 kg is equal to the orbital velocity of another satellite of mass 15×10^3 kg that orbits the same planet at the same height.

2 A satellite moves in a uniform circular path around the Earth at a distance r from the center of the Earth :

(a) **Explain why** the satellite doesn't fall on the Earth although it is affected by the Earth's gravity ?

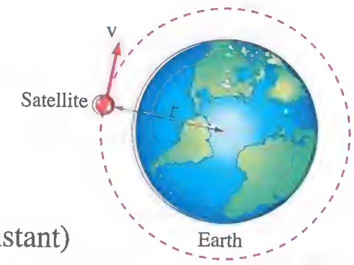
(b) If the attraction force between the satellite and the Earth vanishes suddenly, **what will happen** to the path of the satellite ?

(c) If the orbital velocity of the satellite vanishes suddenly, **what will happen to** the path of the satellite ?

3 **What will happen** if the curvature of a projectile's path equalize with the curvature of the Earth's surface ?

4 The International Space Station orbits the Earth in an orbit of radius r where it completes one revolution around the Earth during time T. If a part of mass 0.1 of the mass of the station is separated from the station, **then what** is the effect of this on the periodic time of the station ?

5 The opposite figure shows a satellite orbiting the Earth at a constant speed (v). The radius of the orbit is (r). **Show that** the periodic time (T) of the satellite is given by the equation :



$$T^2 = \frac{4\pi^2 r^3}{GM}$$

(where : M is the mass of the Earth and G is the gravitational constant)

6 The planet Neptune has 8 moons. Each moon orbit Neptune in a circular path of radius (r) with a period (T). Assuming that Neptune and each moon behave as point masses, **show that** (r) and (T) are related by the expression : $GM_n = \frac{4\pi^2 r^3}{T^2}$

(where : G is the gravitational constant and M_n is the mass of Neptune)

Third Problems

1 A satellite of mass 100 kg moves around the Earth in a roughly circular path of radius 7.4×10^6 m with a speed of 7.4×10^3 m/s, **calculate** the attraction of Earth on the satellite.

(740 N)

2 A satellite rotates in an orbit at height (h) 300 km from the Earth's surface. **Find :**

(a) The orbital velocity.

(b) The periodic time of the satellite around the Earth.

(c) The centripetal acceleration of its motion.

(knowing that : radius of the Earth 6378 km , acceleration due to gravity at the Earth's surface = 9.8 m/s^2)

(8.09×10^3 m/s, 5.18×10^3 s, 9.8 m/s^2)

3 **How high** above the Earth's surface should a satellite rotate so that its periodic time around the Earth equals the periodic time of the Earth's spinning knowing that :

- Earth's day = 24 hour
- Mass of the Earth (M_e) = 5.98×10^{24} kg, universal gravitational constant (G) = 6.67×10^{-11} $N.m^2/kg^2$, radius of the Earth (R) = 6378 km

(3.6×10^7 m)

4 The Moon rotates around the Earth in a circular path of radius 3.85×10^5 km and it completes one revolution in 27.3 days, **calculate** the mass of the Earth.
(where the universal gravitational constant = 6.67×10^{-11} $m^3.kg^{-1}.s^{-2}$) *(6.08×10^{24} kg)*

5 A 1000 kg satellite orbits the Earth in a circular orbit at an altitude of 1000 km. The Earth's mass is 6×10^{24} kg and its radius is 6.4×10^6 m.

(a) **What** is the difference between the force of gravity on the satellite and the centripetal force on the satellite ? **What** is the magnitude of the force of gravity acting on the satellite ?

(b) **What** is the magnitude of the satellite's tangential velocity ?

(c) **What is the value of** the acceleration due to gravity at this altitude ?

(7341 N , 7.4×10^3 m/s , $g = 7.3$ m/s^2)

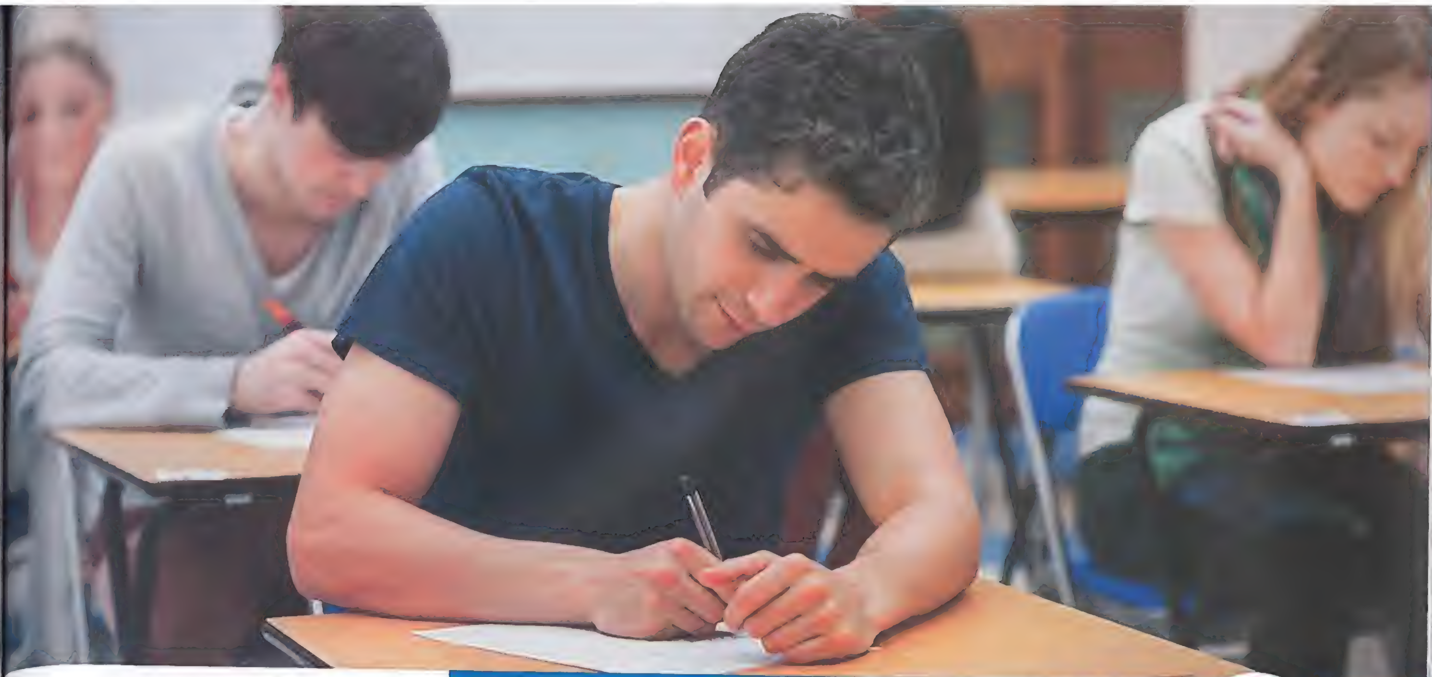
6 A planet of the same mass of the Earth has a radius double the radius of the Earth. **What** is the weight of a body on this planet's surface if its weight on the Earth's surface is 100 N ?

(25 N)

7 A planet has a mass four times the mass of the Earth and a radius double the radius of the Earth, **calculate** the weight of the body on this planet if its weight on the Earth is 150 N.

(150 N)

8 If the mass of the Earth is 81 times the mass of the Moon and the distance between the center of the Earth and the center of the Moon is 60 R. So **on what** distance from the center of the Moon will the point (x) be located ? Where the resultant of the gravitational fields of each of the Moon and the Earth at point (x) equals zero and R = 6378 km *(38268 km)*



MODEL EXAM ON

Chapter 2 Universal Gravitation and Circular Motion

First Choose the correct answer

1 If the orbital radius of a satellite increases four times, the orbital velocity will be ....

ⓐ halved ⓑ doubled

ⓒ decreased to the quarter ⓓ increased four times

---

2 The velocity required for the Earth to rotate around the Sun depends on the ....

ⓐ mass of the Earth only

ⓑ mass of the Sun only

ⓒ mass of the Earth and the Sun and the distance between them

ⓓ mass of the Sun and the distance between them

---

3 If the distance between two objects increases 3 times, the attraction force between them ....

ⓐ doubles ⓑ decreases to its one third

ⓒ increases 9 times ⓓ decreases to one ninth

---

4 The gravitational constant ....

ⓐ is a universal constant

ⓑ changes as the distance between the objects changes

ⓒ changes as the masses changes

ⓓ all the previous

5. A satellite orbits the Earth at a distance of 800 km if the mass of the Earth is 6×10^{24} kg and the Earth's radius is 6.4×10^6 m, what is the satellite's speed ? ....

(a) 10^3 m/s (b) 3.5×10^3 m/s (c) 7.46×10^3 m/s (d) 5×10^6 m/s

6. When climbing from the sea level to the top of Mountain Everest, a hiker changes elevation by 5000 m. By what percentage will the gravitational field of the Earth changes during the climb ? .... (where : the Earth's mass is 6×10^{24} kg, its radius is 6.4×10^6 m)

(a) It will increase by approximately 0.3 %
(b) It will decrease by approximately 0.16 %
(c) It will increase by approximately 12 %
(d) It will decrease by approximately 12 %

7. Two asteroids, one with a mass of 7.12×10^{18} kg and the other with mass 5.33×10^8 kg , are 10×10^{10} m apart. What is the gravitational force on the larger asteroid ? ....

(a) 4.61×10^{-10} N (b) 4.74×10^{-6} N (c) 2.53×10^{-5} N (d) 3.55×10^{-6} N

8. At a place, the value of (g) is less by 1% than its value on the surface of the Earth (where : radius of Earth (R) = 6400 km). The place is ....

(a) 64 km below the surface of the Earth
(b) 64 km above the surface of the Earth
(c) 30 km below the surface of the Earth
(d) 32 km above the surface of the Earth

9. The orbital radii of two satellites rotating around a planet are 2×10^6 m and 1×10^6 m respectively. If the periodic time of the second satellite is 8×10^7 s, then the periodic time of the first equals ....

(a) 5×10^5 s (b) 4×10^6 s (c) 2.3×10^8 s (d) 4.5×10^8 s

10. The Moon has a mass of 7.4×10^{22} kg and a radius of 1.7×10^6 m. What is the force of gravity experienced by a 70 kg astronaut standing on the lunar surface ? ....

(a) 10 N (b) 50 N (c) 100 N (d) 120 N

Second Answer the following questions

11. A satellite rotates at a height of 200 km from the Earth's surface. If the radius of the Earth is 6.4×10^6 m and the universal gravitational constant is 6.67×10^{-11} m^3/kg.s^2,

calculate :

(a) Its orbital velocity.

(b) The gravitational field intensity.

....

....

12. If the ratio between the weight of an object on a planet to that on Earth is (1 : 2), **find** the ratio between the mass of the planet to that of the Earth knowing that the diameter of the planet is half that of the Earth.

....

....

13. A 5 kg mass is at a distance 10 cm away from 15 kg mass, **what** is the resultant gravitational force acting on a 1 kg mass located at the midpoint of the line joining the first two masses ? **Then find** the ratio between this force and the gravitational field intensity at the 1 kg mass.

....

....

....

14. **Calculate** the time required by the Moon to complete one revolution around the Earth in an orbit of radius 3.85×10^5 km, if the mass of the Earth is 6.08×10^{24} kg and the gravitational constant is 6.67×10^{-11} $m^3.kg^{-1}.s^{-2}$.

....

....

....

15. **What is meant by :** The gravitational field intensity of the Earth = 10 N/kg ?

....

16. If the Moon orbits the Earth at a distance of 3.85×10^5 km, **what** is the gravitational field intensity of the Earth at the Moon where the mass of the Earth is 6×10^{24} kg ?

....

....

17. A planet has the same mass as that of the Earth but its diameter is twice that of the Earth. **Calculate** the weight of an object on that planet if its weight on the Earth is 100 N.

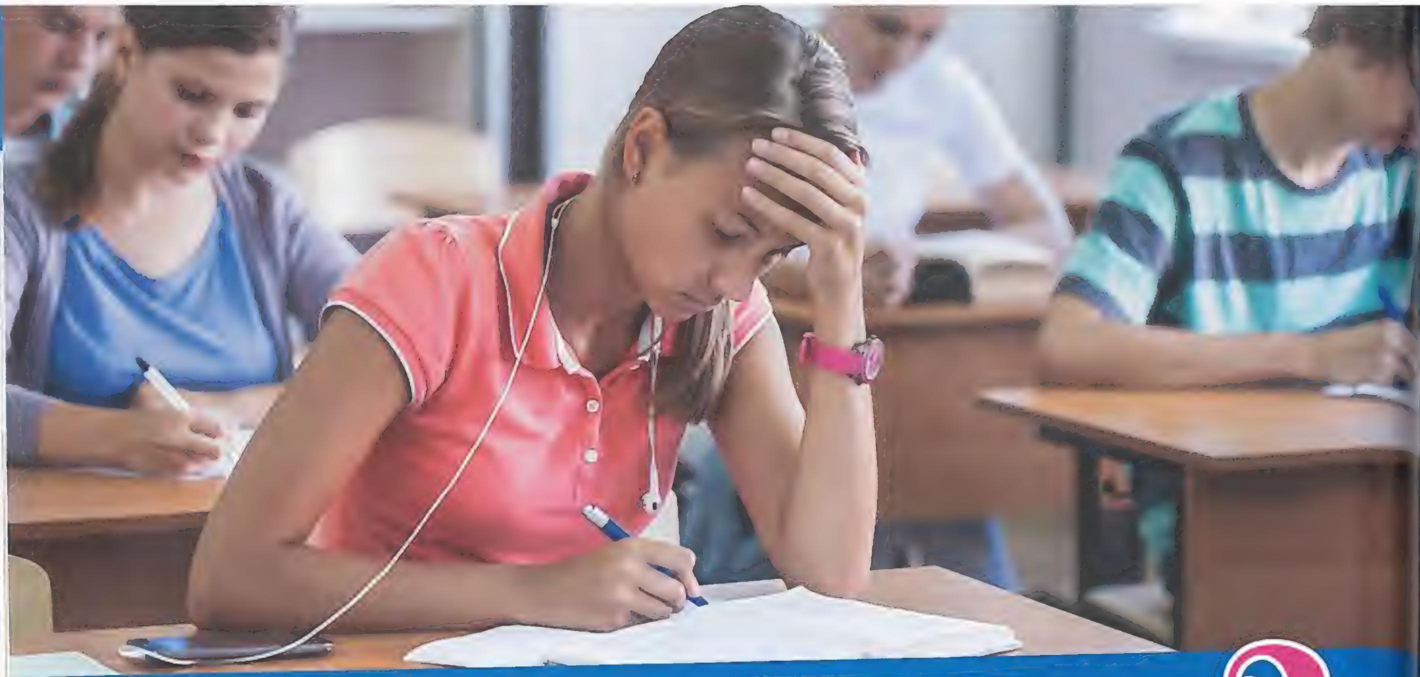
....

....

....

....

....



Accumulative Exam on Units 2 & 3

First Choose the correct answer

1. The ratio between the orbital radii of two satellites rotating around a planet are 3 : 1
If the periodic time of the second satellite is 8×10^7 s, then the periodic time of the first equals ....

ⓐ 5×10^5 s ⓑ 1.5×10^8 s ⓒ 2.3×10^8 s ⓓ 4.5×10^8 s

2. A satellite orbits the Earth at a distance of 100 km. The mass of the satellite is 100 kg, while the mass of the Earth is approximately 6×10^{24} kg. The radius of the Earth is approximately 6.4×10^6 m. What is the approximate force of gravity acting on the satellite ? ....

ⓐ 4×10^4 N ⓑ 6.2×10^6 N ⓒ 4×10^8 N ⓓ 6.2×10^9 N

3. If R is the radius of the Earth, the height at which the weight of a body becomes $\frac{1}{4}$ its weight on the surface of the Earth is ....

ⓐ 2R ⓑ R ⓒ $\frac{R}{2}$ ⓓ $\frac{R}{4}$

4. Two asteroids are at a distance (r) from each other in space. If one of the satellites has a mass (m) and the other has a mass 2 m, which one will have the smaller acceleration ? ....

ⓐ m
ⓑ 2 m
ⓒ They both will have the same acceleration
ⓓ Neither will have acceleration

5 A racing car can accelerate by changing ....

ⓐ its direction only
ⓑ its speed only
ⓒ either its direction or speed
ⓓ its direction and speed

6 An object of mass 0.5 kg at rest, started to fall from a height of 180 cm from the surface of Earth. Its momentum when it reaches the Earth's surface is ....

ⓐ 3 kg.m/s
ⓑ 5 kg.m/s
ⓒ 6 kg.m/s
ⓓ 9 kg.m/s

7 An aircraft executes a horizontal loop of radius 1 km with a steady speed of 900 km/h. The ratio of its centripetal acceleration to the acceleration due to gravity is ....

ⓐ 9.2
ⓑ 6.25
ⓒ 5
ⓓ 8.25

8 A car of mass 840 kg moves on a circular path with constant speed of 10 m/s. It is turned after travelling 660 m on the road through 90°. The centripetal force acting on the car is ....

ⓐ 324 N
ⓑ 2640 N
ⓒ 284 N
ⓓ 200 N

9 A satellite orbits the Earth at a distance of 100 km. The mass of the satellite is 100 kg. While the mass of the Earth is approximately 6×10^{24} kg. The radius of the Earth is approximately 6.4×10^{6} m. What is the approximate force of gravity acting on the satellite ? ....

ⓐ 4×10^{4} N
ⓑ 6.2×10^{6} N
ⓒ 4×10^{8} N
ⓓ 9.5×10^{2} N

10 An object of mass 1.5 kg is left to fall from the top of a building. If it reached half of the building within 5 seconds, then its momentum at the moment it touches the ground is ....

ⓐ 106.07 kg.m/s
ⓑ 109.03 kg.m/s
ⓒ 113.05 kg.m/s
ⓓ 120.11 kg.m/s

Second Answer the following questions

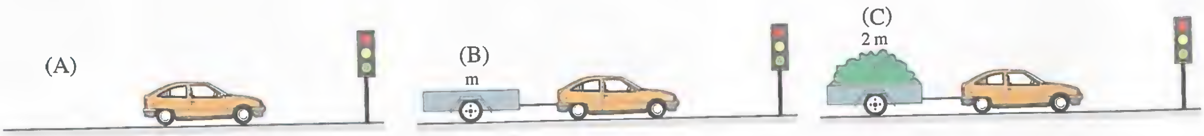
11 A car of mass 1000 kg moving with a velocity 17.6 m/s collide with a tree and moved with a uniform deceleration until it stopped through a distance of 0.7 m.
Calculate the force of the tree which stopped the car.

....

....

....

12 The following figures **illustrate** three similar cars each of mass (m), **compare** their accelerations ignoring the frictional forces.



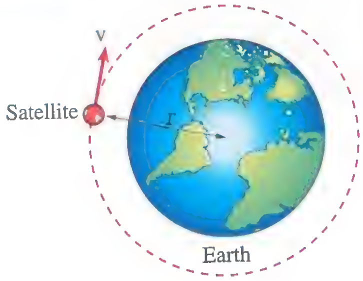
....

....

....

13 The following figure shows a satellite orbiting the Earth at a constant speed (v). The radius of the orbit is (R). **Show that the orbital period (T) of the satellite is given by the equation :**

$$T^2 = \frac{4\pi^2 r^3}{GM}$$



(where : M is the mass of the Earth, G is the gravitational constant)

....

....

14 A force of 100 N acted on a body of mass 10 kg and changed its velocity from 10 m/s to 20 m/s. **Calculate** the distance covered by the body due to this force.

....

....

....

....

15 **Explain why** it is dangerous to move at high velocities in curved roads ?

....

....

....

....

16 **Determine the type of centripetal force in each of the following cases :**
(Gravitational pull – Electric attraction – Tension force – Reaction force – Lifting force)


(a) Rotation of a bird


(b) Rotation in flying chairs


(c) Turning of a train

....

17 **Write down the slope and the mathematical relation for the opposite graph.**

....

....

UNIT 4

Work and Energy in Our Daily Life

Unit objectives

By the end of this unit, the student will be able to :

Chapter 1 :

- Explain the scientific concept of work.
- Deduce that work is a scalar quantity (not a vector quantity).
- Derive the units of energy.
- Deduce the mathematical expression for each of the kinetic energy and the potential energy.
- Draw a conclusion that the potential energy is the work done.
- Compare between the kinetic energy and the potential energy.

Chapter 2 :

- Apply the mutual interchange between the kinetic energy and the potential energy when projecting an object vertically upwards as an example for the law of conservation of energy.
- Apply the law of conservation of energy on some situations in everyday experience.

Chapter 1

LESSON ONE

Work

- The meaning of work in Physics is different from that used in everyday life. Work does not mean that a tough task is done. To do work on a body, the body must move a certain displacement due to the force acting on it. If the body doesn't move, so there is no work done whatever the value of the force acting on the body.
- **In Physics, there are two conditions for work to be done :**

  (1) An acting force.

  (2) A displacement in the direction of the line of action of the force.

This can be illustrated by the following two examples :

1. The player who lifts weights up does work.

2. The person who pushes the wall does no work.

Because

- The force acting on the weights moves them upwards through a distance in the direction of the force.
- The force acting on the wall fails to move it.

  The wall remains motionless.

Conclusion

- When a force acts on an object to move it through a certain displacement in the direction of the line of action of the force, it is said that the force does work.

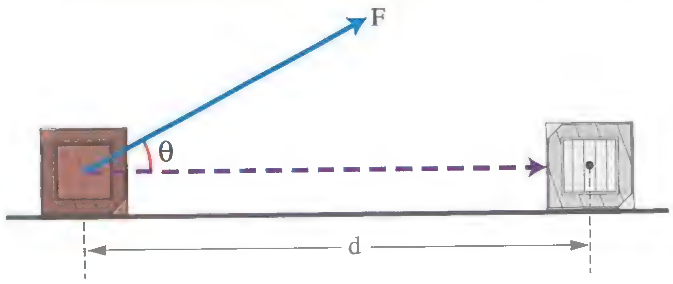
Work (W) is determined from the relation

$$W = \vec{F}.\vec{d} = Fd \cos \theta$$

F: The acting force

d: The displacement of the object in the direction of the line of action of the force

θ: The angle between the direction of the force and the direction of the displacement



The measuring unit of Work is $kg.m^2/s^2$ that is equivalent to N.m or joule (J) and its dimensional formula is ML^2T^{-2}

EKB

⊙ From the previous, work and its measuring unit can be defined as follows :

Work :

It is the dot product of the acting force (F) and the displacement (d) in the direction of the line of action of the force.

Joule :

It is the work done by a force of 1 N to move an object through a displacement of 1 m in the direction of the line of action of the force.

Note :

Although both force and displacement are vector quantities, work is a scalar quantity.

Because work is the dot product of the force and the displacement.

▶ **For Example :** The work done to move a cart 5 m forward is the same work done to move the cart 5 m backward.

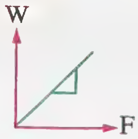
The factors that affect work :

$W = Fd \cos\theta$

1 **The acting force on the body :**

Work is directly proportional to the acting force at constant displacement and constant angle between force and displacement.

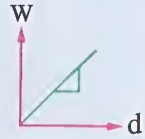
Slope $= \dfrac{\Delta W}{\Delta F} = d \cos\theta$



2 **The displacement of the body :**

Work is directly proportional to the displacement at constant force and constant angle between force and displacement.

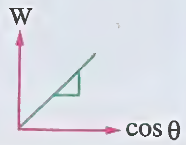
Slope $= \dfrac{\Delta W}{\Delta d} = F \cos\theta$



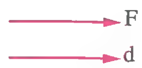
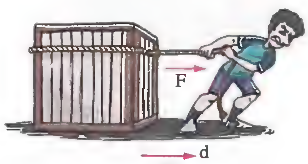
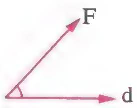
3 **Cosine the angle between the force and the displacement :**

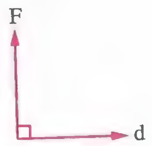
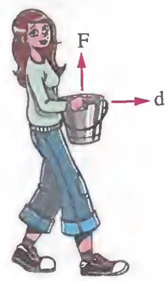
Work is directly proportional to cosine the angle between the force and the displacement at constant force and constant displacement.

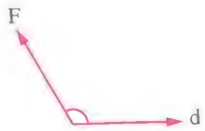
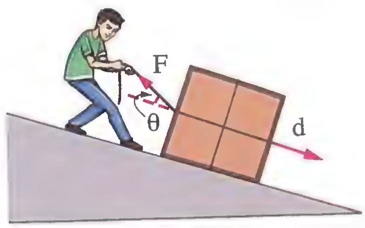
Slope $= \dfrac{\Delta W}{\Delta \cos\theta} = Fd$



The effect of the angle between force and displacement on work :

The value of the angle (θ)	The work done
$\theta = 0°$ 	• Work done has a **maximum positive value** when the direction of the force is in the same direction of the displacement. $W = Fd \cos 0 = Fd$  **Example :** A person pulling an object through a certain distance.
$0° < \theta < 90°$ 	• Work done has a **positive value** due to the angle between the direction of the acting force on the body and the displacement is less than 90°, so cosine the angle is a positive value (the person does work on the object). $W = Fd \cos\theta = +ve$ value  **Example :** A person pulling an object.

<table>
<tr>
<td>θ = 90°

</td>
<td>• Work done vanishes when the direction of the force is perpendicular to the direction of the displacement. $W = Fd \cos 90° = 0$


▶ Example :
A person moves horizontally while carrying a bucket where the direction of the horizontal displacement of the person is perpendicular to the direction of the force that the person's hand exerts on the bucket.</td>
</tr>
<tr>
<td>180° > θ > 90°

</td>
<td>• Work done has a negative value due to the angle between the direction of the acting force on the body and the displacement is greater than 90° and is less than 180°, so cosine the angle is a negative value (the object does work on the person).


$W = Fd \cos \theta =$ -ve value
▶ Example :
A person pulling an object while the object is moving opposite to the direction of the force.</td>
</tr>
<tr>
<td>θ = 180°

</td>
<td>• Work done has a maximum negative value when the direction of the acting force on the object is opposite to the direction of its displacement.


$W = Fd \cos 180° = -Fd$
▶ Example :
The work done by the frictional forces (as the force of brakes).</td>
</tr>
</table>

1 Test yourself

Answered

The satellites stay in their orbits around the Earth without the need of any amount of fuel. **Explain this statement.**

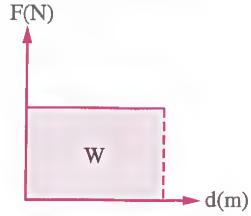
....

....

Finding work done graphically

◉ Work done can be found graphically by using the (force – displacement) graph, as follows :

If a constant force (F) acted on a body and displaced it through a displacement (d) in the same direction of the force then ($\theta = 0°$) and when representing the relation (force versus displacement) graphically, we get the opposite graph :

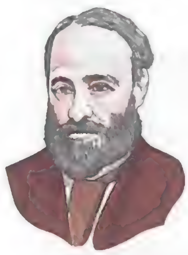


$\because$ Work = Force × Displacement

$\therefore$ **Work (graphically) = The area below the (force – displacement) curve**

Distinguished scientists

James Joule (1818 – 1889) :



- An English scientist who was the first to realize that work generates heat.
- In one of his experiments he found that water temperature at the bottom of a waterfall is higher than that at the top; concluding that a part of water energy is converted into heat.

Example 1

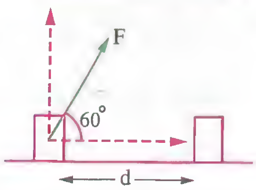
A cart of mass 20 kg is pulled by a force of 50 N. The line of action of the force makes an angle of 60° to the direction of displacement. Find the work done by the force to displace the cart through 4 m (neglecting friction).

Solution

m = 20 kg | F = 50 N | $\theta = 60°$ | d = 4 m | W = ?

$W = Fd\cos\theta$

$= (50)(4)(\cos 60°) = 100$ J



Example 2

Calculate the work done by a girl on a bucket of mass 300 g that is carried by her through a displacement of 10 m in the horizontal direction. Then, calculate the work done by a boy to lift a bucket of the same mass through a displacement of 10 cm in the vertical direction. (where : $g = 10\ m/s^2$, the force of tension = The bucket's weight)

Solution

$m = 300\ g$ | $d_{girl} = 10\ m$ | $d_{boy} = 10\ cm$ | $g = 10\ m/s^2$ | $W_{girl} = ?$ | $W_{boy} = ?$

- The work done by the girl on the bucket :

$\because$ The force exerted by the girl is perpendicular to the displacement of the bucket.

$\therefore W_{girl} = 0$

- The work done by the boy :

$F = mg = \frac{300}{1000} \times 10 = 3\ N$

$\because$ The force and the displacement are in the same direction.

$\therefore \theta = 0$

$W_{boy} = Fd_{boy} \cos\theta = (3)\left(\frac{10}{100}\right)(\cos 0) = 0.3\ J$

Example 3

A force of 100 N acts on a static body to move it horizontally. If the body's velocity reaches 20 m/s after 5 s, calculate the work done by this force after 5 s from the start motion neglecting the friction forces.

Solution

$F = 100\ N$ | $v_i = 0$ | $v_f = 20\ m/s$ | $t = 5\ s$ | $W = ?$

Clue

$\because$ *The body is affected by a constant force.*

$\therefore$ *The body moves with uniform acceleration, so its displacement can be determined by using the equations of motion with uniform acceleration or by using the average velocity.*

- From the first equation of motion :

$$a = \frac{v_f - v_i}{t} = \frac{20 - 0}{5} = 4\ m/s^2$$

- From the second equation of motion :

$$d = v_i t + \frac{1}{2} a t^2 = 0 + \left(\frac{1}{2} \times 4 \times (5)^2\right) = 50\ m$$

$W = Fd = 100 \times 50 = 5000\ J$

Another Solution :

$$\bar{v} = \frac{d}{t} = \frac{v_f + v_i}{2}$$

$$\frac{d}{5} = \frac{20 + 0}{2}$$

$d = 50\ m$

$W = Fd = 100 \times 50 = 5000\ J$

Example 4

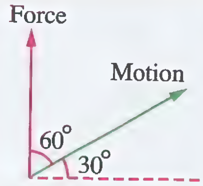
A worker that carries a box of mass 40 kg climbs up stairs of length 20 m as shown in the figure. If the free fall acceleration equals 10 m/s^2, find the work done on the box.

Solution

m = 40 kg | d = 20 m | $\theta = 60°$ | g = 10 m/s^2 | W = ?

Clue

When the worker climbs up the stairs, he acts on the box by a force in a direction that inclines on the direction of motion (displacement) at angle 60°.



$F = w = mg = 40 \times 10 = 400$ N

$W = Fd\cos\theta$

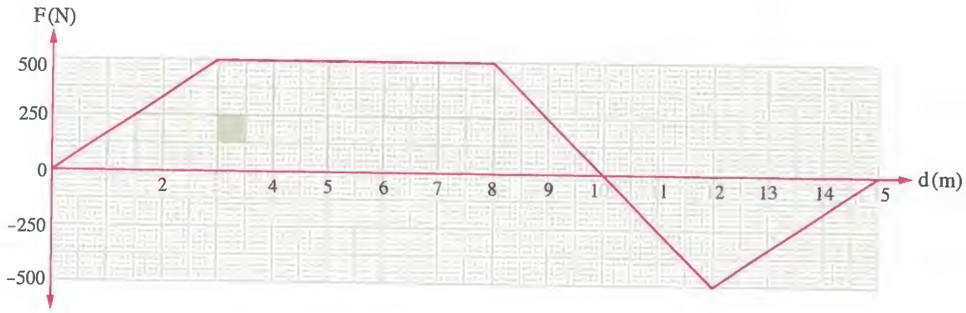
$= 400 \times 20 \times \cos 60° = 4000$ J

Example 5

The following figure represents the change of the acting force on a body that moves in a certain direction, calculate the work done by the force when the body moves :

(a) from d = 0 to d = 10 m

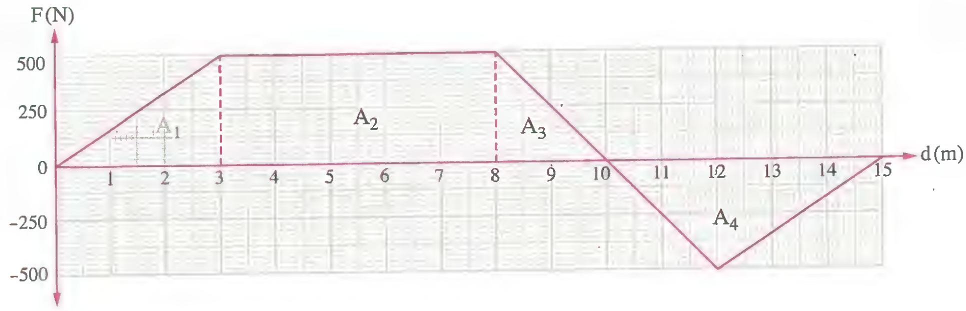
(b) from d = 0 to d = 15 m



Solution

Clue

The work done is determined graphically by the area below the (force - displacement) curve, so the area below the curve should be divided into parts of areas that can be calculated.



(a) $W_1 = A_1 + A_2 + A_3$

$= (0.5 \times 3 \times 500) + (5 \times 500) + (0.5 \times 2 \times 500) = 3750\ J$

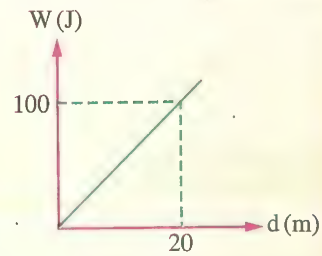
(b) $W_2 = A_1 + A_2 + A_3 + A_4$

$= W_1 + A_4 = 3750 + \left(0.5 \times 5 \times (-500)\right) = 2500\ J$

2 Test yourself

Answered

1 The opposite figure represents the relation between the work done (W) by a force (F) and the displacement (d), if the angle between the force and the displacement is 30°, **calculate** the force (F).

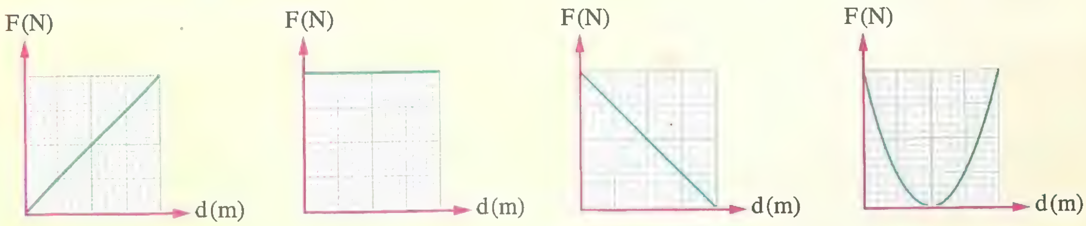


....

....

....

2 **Choose** : The following graphs represent the relation between the force (F) that acts on a group of moving bodies and the displacement (d) moved by these bodies in the same direction of the force due to the effect of this force on them, so on which of these bodies the work done is the biggest ? ....



ⓐ ⓑ ⓒ ⓓ

QUESTIONS ON
Chapter 1
LESSON ONE

Work

Interactive test

First Multiple choice questions

1 The dimensions of work are ....

(a) MLT^{-1} (b) MLT^{-2} (c) ML^2T^{-2} (d) ML^2T^{-1}

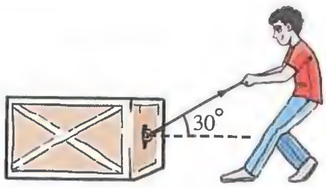
2 Joule is equivalent to .... **(Choose two answers)**

(a) N.m (b) N/m (c) $N.m^2$ (d) $kg.m^2/s^2$ (e) $kg.m/s^2$

3 The work done is maximum when the angle between the direction of the force that acts on a body and the direction of its displacement equals ....

(a) zero (b) 45° (c) 60° (d) 90°

4 When a box moves in a direction that makes an angle 30° with the direction of the force acting on it as in the opposite figure , then the work done on the box by this force will be ....



(a) zero (b) maximum

(c) half the maximum value (d) $\frac{\sqrt{3}}{2}$ the maximum value

5 The work is negative if the direction of the displacement .... direction of the force.

(a) is in the same (b) is normal to the

(c) opposes the (d) is inclined by an acute angle on the

6 In the car, the work done by the brakes ....

(a) is positive (b) is negative

(c) equals zero (d) may be positive or negative

7 If the force acting on a body is doubled such that the body covers the same displacement , then the work done ....

(a) increases 4 times (b) is doubled

(c) decreases to its half (d) remains constant

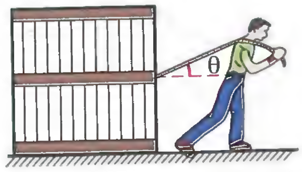
8 A body moves in a uniform circular motion under the effect of a resultant force of 40 N. If the body covered a displacement of 10 m, then the work done on the body equals ....

(a) zero (b) 4 J (c) 40 J (d) 400 J

9 A child of mass 40 kg moves horizontally on a skating surface, then the work done by his weight when he moves a distance of 20 m is ....

(a) zero (b) 800 J (c) 4000 J (d) 8000 J

10 The opposite figure shows a man that pulls a box with a force (F) to displace it a displacement (d), so the magnitude of the work done by the man on the box decreases by .... **(Choose two answers)**



ⓐ decreasing the acting resultant force on the box

ⓑ increasing the acting resultant force on the box

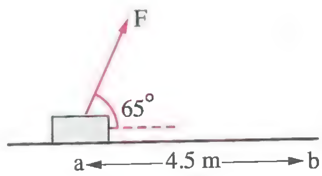
ⓒ decreasing the angle between the force and the displacement

ⓓ increasing the angle between the force and the displacement

ⓔ increasing the magnitude of the displacement moved by the box

---

11 A body of mass 5 kg is placed on a smooth horizontal plane. A force of 40 N acts on the body to move it from rest a distance of 4.5 m from point a to b as shown in the opposite figure. If the friction force is 15 N, then the .... **(Choose two answers)**



ⓐ work done on the body by the force during its motion from a to b equals zero

ⓑ work done on the body by the force during its motion from a to b equals 8.6 J

ⓒ work done on the body by the force during its motion from a to b equals 112.5 J

ⓓ velocity of the body at b equals 1.85 m/s

ⓔ velocity of the body at b equals 10.6 m/s

---

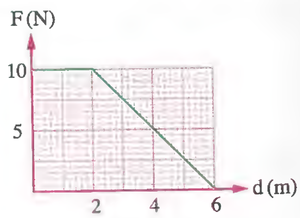
12 A mother pushes her child's cart with a constant velocity on a straight horizontal road by a force that makes with the horizontal an angle of 60°. If a friction force of 20 N acts on the cart, then the work done by the mother to move the cart a distance of 5 m equals ....

ⓐ 100 J ⓑ 80 J

ⓒ 50 J ⓓ 40 J

---

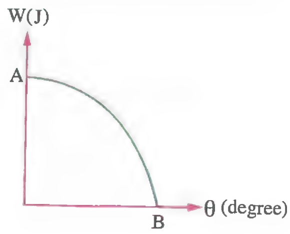
13 The opposite graph shows the relation between the horizontal force that acts on a body and the horizontal displacement covered by the body due to this force, then the work done by this force is ....



ⓐ 20 J ⓑ 40 J

ⓒ 50 J ⓓ 60 J

14 The opposite graph shows the relation between the work done (W) on a body and the angle (θ) between the acting force (F) on the body and the displacement (d) moved by it due to the effect of this force, then the value of ....



(Choose two answers)

ⓐ A equals $\frac{1}{2}$ Fd ⓑ A equals Fd ⓒ B equals 0°

ⓓ B equals 30° ⓔ B equals 90°

Second Essay questions

1 **Explain the following sentences :**

(1) Work is a scalar quantity.

(2) • The centripetal force does no work.

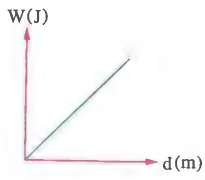
• The electron during its rotation around the nucleus does no work.

• The satellite during its rotation around Earth does no work.

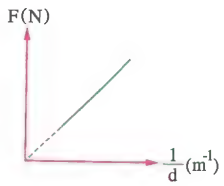
• When a body moves in a circular path with constant velocity, it does no work.

(3) When a body moves with constant velocity on a frictionless horizontal surface , the total work done on it equals zero.

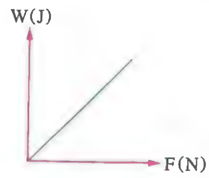
2 **Write down the mathematical relation and the slope of each graph :**



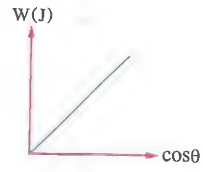
(1)



(2)



(3)



(4)

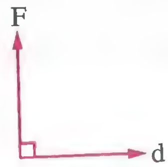
Where : (W) is the work done, (d) is the displacement, (F) is the resultant force and (θ) is the angle between the force and the displacement.

3 **Complete the following table :**

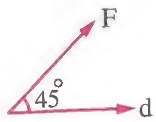
Force (F)	Displacement (d)	The angle (θ) between the displacement and the force	Work (W)
5 N	4 m	.... (1)	20 J
20 N	100 m	45°	.... (2) ....
100 N	.... (3)	60°	4330 J

4 **If a force (F) acts on a body to move it a displacement (d), arrange the following figures in a descending order according to the value of the work done in each by explaining your answer :**

(1)



(2)



(3)

5 **Explain in each of the following if a work is done or not. Give reason for your answer.**

(1) A person carries a bag and climbs up stairs.

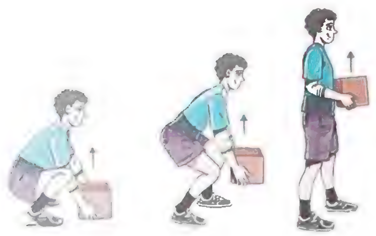
(2) A person tries to push a car but he can't move it.

(3) A person pushes a baby cart.

6 **The arrow in each figure shows the direction of the acting force. Which of these figures shows that there is a work done by this force ? Give reason for your answer.**

(a)

(b)



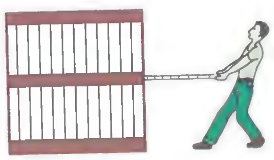
(c)

(d)

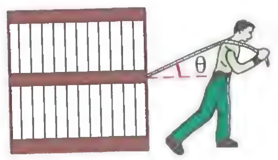
7 **Mention an example for an object where the work done on it is :**

(a) equal to zero. (b) maximum. (c) positive. (d) negative.

8 **If the object in each of the following cases (a) and (b) moves the same displacement, so in which case the work done is maximum ? Give reason for your answer.**



(a)



(b)

Third Problems

1 **Find** the work done to push a cart by a force of 20 N through a displacement of 3.5 m.

(70 J)

2 A force of 100 N acts on an object to displace it through 2.5 m.

Find the work done by this force in the following cases :

(a) If the force acts in the same direction of the object's motion.

(b) If the force's direction makes an angle of 60° with the direction of the object's motion.

(c) If the force acts perpendicular to the direction of the object's motion. *(250 J, 125 J, 0)*

3 The following table shows the relation between the work (W) in (J) and the distance (d) in (m) for a body that moves in a straight line under the effect of a constant force :

W (J)	10	15	20	25	30	50
d (m)	2	3	4	5	6	10

(a) **Draw** a graph relating (W) on the y-axis and (d) on the x-axis.

(b) **From the graph find** the force acting on the body, if the body moves in the same direction of the force's direction. *(5 N)*

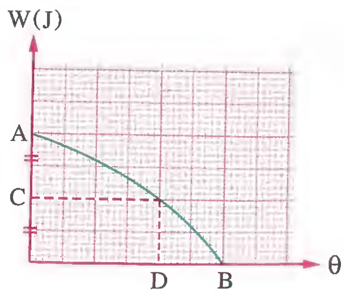
4 A motorcycle of mass 200 kg moves in a straight line under the effect of the motor's force of 500 N. If the frictional force is 100 N for every 100 kg of the motorcycle's mass, **calculate** the work done on the motorcycle to move it a distance of 50 m. *(15000 J)*

5 A force of 200 N acts on a static object of mass 50 kg to move it in its direction. **Calculate** the work done by this force during 5 seconds. *(10^4 J)*

6 The opposite graph shows the relation between the work done and the angle between the direction of the force and the direction of motion. If you know that the force that causes motion is 100 N and the displacement is 5 m. **Find :**

(a) The work done at (A) and (C).

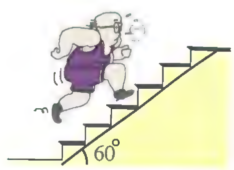
(b) The value of the angle at (D) and (B).

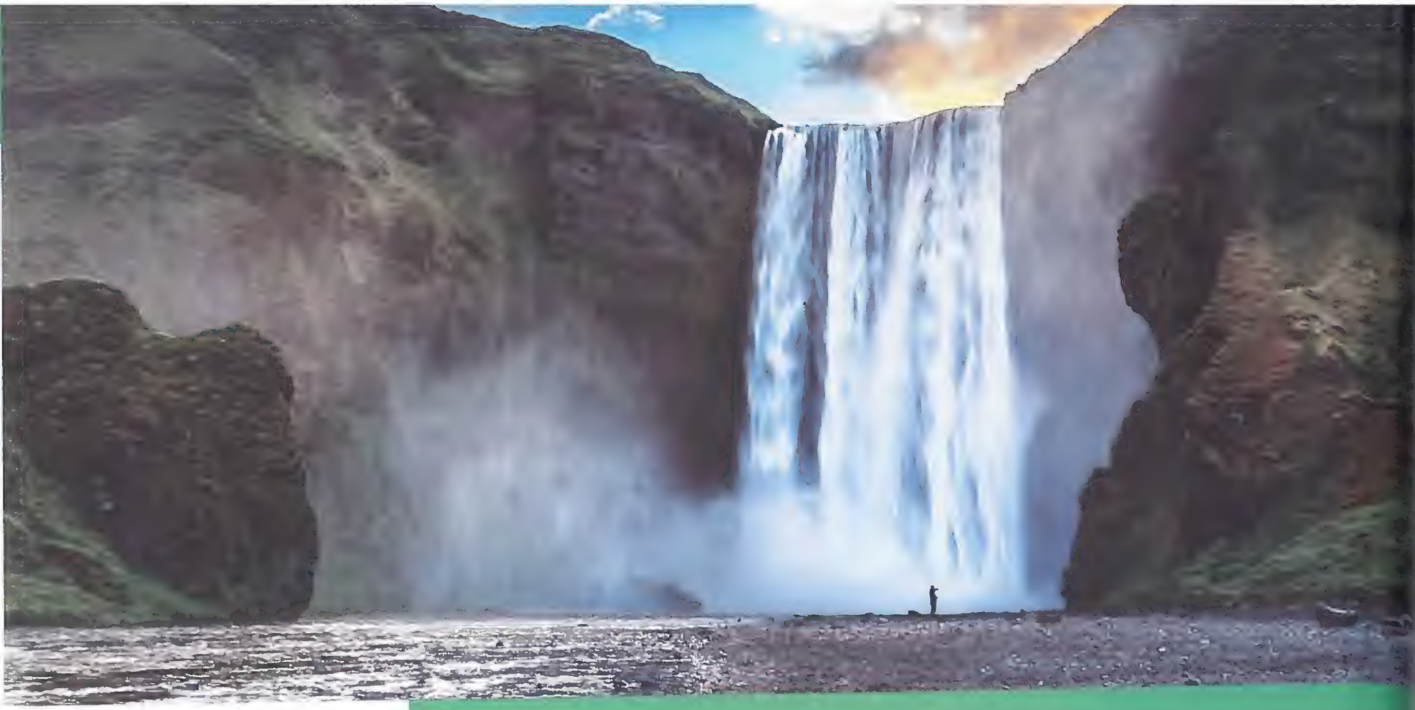


(500 J, 250 J, 60°, 90°)

7 In the opposite figure, a man of mass 70 kg climbs upstairs of length 50 m. **Calculate** the work done if $g = 10\ m/s^2$

(30.31×10^3 J)





Chapter 1

LESSON TWO

Energy

- Man needs **energy** to exert effort (do work) and without energy no task can be performed.
- **For example :** When a person kicks a ball, the chemical energy stored inside his body is converted into another form of energy which causes the movement of the ball.

The measuring unit of Energy is The joule (J) (the same measuring unit of work) that is equivalent to $kg.m^2/s^2$ or N.m and its dimensional formula is ML^2T^{-2}

Energy :

It is the capacity (ability) to do work.

The energy has different forms.

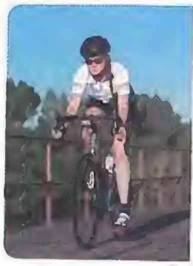
From the forms of energy

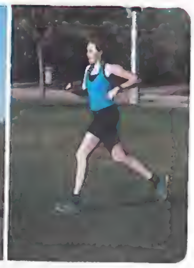
- First: Kinetic energy (KE)
- Second: Potential energy (PE)

EKB

First Kinetic energy (KE)

◉ When work is done to move an object, this work is acquired by the object as **kinetic energy**.





Kinetic energy :

It is the energy possessed by the object due to its motion.

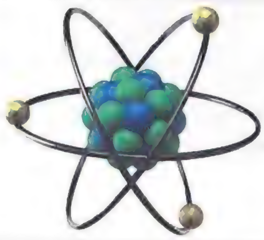
Examples of kinetic energy :

1. A man running.

2. The water flowing through a dam.

3. The water waves hitting the shore.

4. An electron orbiting a nucleus.



Finding the kinetic energy of an object

◉ If a force (F) acts on an object of mass (m) at rest to move it at a uniform acceleration (a) to reach velocity (v_f) after moving a displacement (d), thus :

Proof

From the third equation of motion : $v_f^2 = v_i^2 + 2\,ad$

$\because v_i = 0 \qquad \therefore v_f^2 = 2\,ad \quad , \qquad d = \frac{v_f^2}{2\,a}$

Multiplying both sides by the force (F) :

$\therefore Fd = \frac{1}{2} \times \frac{F}{a} \times v_f^2$

From Newton's second law :

$\because \frac{F}{a} = m$

$$\therefore Fd = \frac{1}{2} m v_f^2$$

Fd

Represents the **work done** to move the body.

$\frac{1}{2} m v_f^2$

Represents the **kinetic energy (KE)** which is the form of energy into which the work is converted.

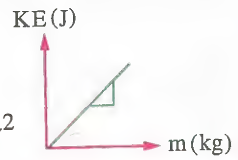
$$\therefore KE = \frac{1}{2} m v^2$$

The factors that affect kinetic energy of an object :

1 The object's mass (m) :

Kinetic energy is directly proportional to the object's mass at constant speed.

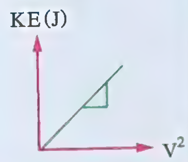
Slope $= \frac{\Delta KE}{\Delta m} = \frac{1}{2} v^2$



2 The object's square velocity (v^2) :

Kinetic energy is directly proportional to the object's square velocity at constant mass.

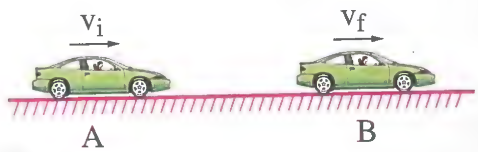
Slope $= \frac{\Delta KE}{\Delta v^2} = \frac{1}{2}$ m



$$KE = \frac{1}{2} m v^2$$

Notes :

- Kinetic energy is a **scalar quantity** because it is the product of two scalar quantities which are the object's mass and the square of its velocity.
- In the opposite figure, the work done by the car to move from position (A) to position (B) :



$$W = \frac{1}{2} m v_f^2 - \frac{1}{2} m v_i^2$$
$$= \frac{1}{2} m (v_f^2 - v_i^2) = \Delta(KE)$$

- **If the work done on a body is :**
  - **Positive :** the kinetic energy of the body increases by increasing the work done and the velocity of the body increases.

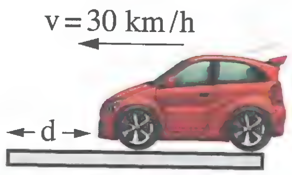
    i.e. The resultant force acting on the body is in the same direction of its motion.

- **Negative :** the kinetic energy of the body decreases by decreasing the work done and the velocity of the body decreases.
  i.e. The resultant force acting on the body is in the opposite direction of its motion.
- **Equal to zero :** the kinetic energy remains constant which means that the velocity of the body remains constant.
  i.e. The resultant force acting on the body vanishes.

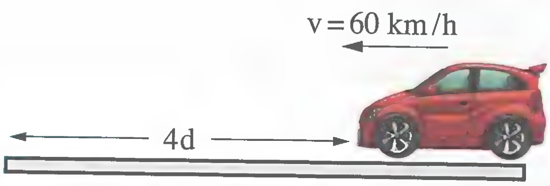
Life application

⊙ From the relation ($KE = \frac{1}{2}mv^2 = Fd$) we find that the work done on a body in the form of kinetic energy is directly proportional to square the velocity of the body, then :

On applying the brakes to stop a car that moves with a velocity of 30 km/h, the car will cover a distance (d) before stopping.



On applying the brakes (with the same force used in the first case) to stop the same car when it moves with a velocity of 60 km/h it will cover a distance (4 d) before stopping.



Example 1

Calculate the kinetic energy of a car of mass 2000 kg that is moving with at a velocity of 72 km/h.

Solution

$m = 2000$ kg | $v = 72$ km/h | $KE = ?$

Converting the unit of velocity into m/s :

$$v = \frac{72 \times 1000}{60 \times 60} = 20 \text{ m/s}$$

$$KE = \frac{1}{2}mv^2$$

$$= \frac{1}{2} \times (2000)\,(20)^2 = 4 \times 10^5 \text{ J}$$

Example 2

A car of mass 1200 kg is moving on a horizontal road, calculate the work done by the car to increase its velocity from 5 m/s to 10 m/s.

Solution

$m = 1200$ kg | $v_i = 5$ m/s | $v_f = 10$ m/s | $W = ?$

Clue

The work done by the car to increase its velocity equals the change in its kinetic energy.

$$W = \Delta(KE) = (KE)_f - (KE)_i$$
$$= \frac{1}{2} mv_f^2 - \frac{1}{2} mv_i^2$$
$$= \frac{1}{2} m (v_f^2 - v_i^2)$$
$$= \frac{1}{2} \times 1200 ((10)^2 - (5)^2)$$
$$= 4.5 \times 10^4 \text{ J}$$

Example 3

A car moves with a velocity of 15 m/s, when the driver applies the brakes, the car stops after covering a distance of 20 m, calculate the distance that would be covered by the car before stopping if the driver applies the brakes by the same force when the car is moving with a velocity of 30 m/s (using the work and energy equations).

Solution

$(v_i)_1 = 15$ m/s | $(v_f)_1 = 0$ | $d_1 = 20$ m | $(v_i)_2 = 30$ m/s | $(v_f)_2 = 0$ | $d_2 = ?$

$$W = -Fd \quad ①$$
$$W = \Delta(KE) = \frac{1}{2} mv_f^2 - \frac{1}{2} mv_i^2$$
$$W = -\frac{1}{2} mv_i^2 \quad ②$$

From equations ① and ② :

$$Fd = \frac{1}{2} mv_i^2$$

$\because$ F and m are constant.

$$\therefore \frac{d_1}{d_2} = \frac{(v_i)_1^2}{(v_i)_2^2}$$

$$\therefore \frac{20}{d_2} = \frac{(15)^2}{(30)^2} \qquad \therefore d_2 = 80 \text{ m}$$

Example 4

Two bodies (x), (y) have the same mass if their kinetic energies are 100 J, 900 J respectively and the linear momentum of body (x) is 20 kg.m/s, calculate the linear momentum of body (y).

Solution

$(KE)_x = 100$ J | $(KE)_y = 900$ J | $p_x = 20$ kg.m/s | $p_y = ?$

$\because KE = \frac{1}{2} mv^2$ $\quad\therefore KE \propto v^2$ ①

$\because p = mv$ $\quad\therefore p \propto v$ ②

From equations ① and ② :

$\therefore p \propto \sqrt{KE}$ $\quad\therefore \frac{p_x}{p_y} = \sqrt{\frac{(KE)_x}{(KE)_y}}$

$\therefore \frac{20}{p_y} = \sqrt{\frac{100}{900}}$ $\quad\therefore p_y = 60$ kg.m/s

Practical Experiment

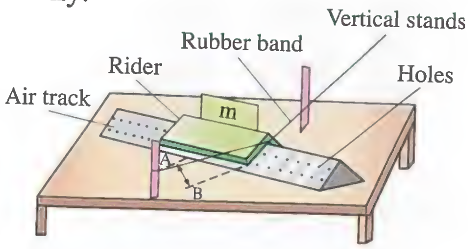
Determination of the kinetic energy of a moving object

1. Experiment Objective :

- Measuring the kinetic energy of a moving object practically.

2. Tools :

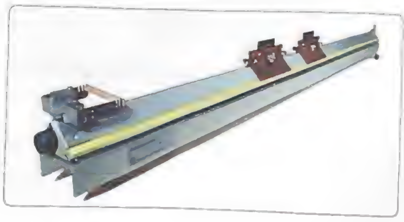
A rider of mass (m) is displaced along an air track (frictionless surface) through a given distance using a rubber band stretched between two vertical stands as in the opposite figure.



Determination of kinetic energy using the air track

3. Procedure :

1. Displace the rider through a given distance (d) from position (A) to position (B) where the rider stretches the rubber band.
2. Release the rider to rush back at a certain velocity (v).
3. Measure the time taken by the rider while moving along the air track using an electric watch connected to a photoelectric cell.



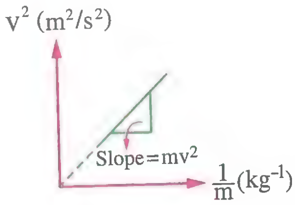
4. Determine the rider speed (v) using the relation : $v = \frac{d}{t}$

5. Repeat the previous procedure several times by changing the mass of the rider (m) and determine the rider speed (v) each time. Note that the rider should be displaced through the same distance each time. Record the results in the table below :

Rider mass (m) kg	Time (t) s	Rider speed (v) m/s	Reciprocal of mass ($\frac{1}{m}$) kg^{-1}	Square of speed (v^2) m^2/s^2

6. Plot a graph between the square of the speed (v^2) on the ordinate and the reciprocal of the mass (1/m) on the abscissa. You will get a straight line. Therefore, $v^2 \propto \frac{1}{m}$

The slope of the line $= \frac{\Delta v^2}{\Delta(\frac{1}{m})} = mv^2 = 2\ KE$



1 Test yourself

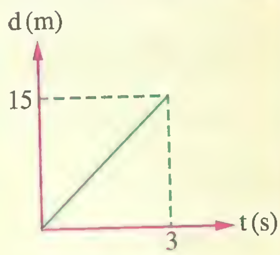
Answered

The opposite (displacement - time) graph describes the motion of a body of mass 10 kg, **calculate** the kinetic energy of this body.

....

....

....



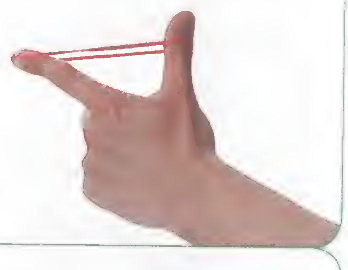
Second Potential energy (PE)

- When work is done on a body to change its position, this work is stored in the body as a form of energy which is called **potential energy**.

Potential energy :

It is the energy stored in objects because of their new positions or states.

Examples of potential energy :

1 Stored potential energy in a compressed or elongated spring. **(elastic potential energy)**	When a spring is compressed or elongated, its molecules acquires a new position and they store elastic potential energy. Then, the spring does work to release this energy and restore its original position.	
2 Stored potential energy in a stretched rubber band. **(elastic potential energy)**	When a rubber band is stretched, its molecules acquires a new position and they store elastic potential energy. So when removing the acting force on the rubber band, the band shrinks to release this energy and restore its original shape.	
3 Stored potential energy in an object that is raised off the ground. **(gravitational potential energy)**	Gravitational potential energy depends on the object's position relative to the Earth's surface (relative to the gravitational field).	
4 Stored potential energy in the electrons inside a battery. **(chemical potential energy)**	Electrons flow when the battery is connected to a closed circuit.	

Finding the potential energy of an object

Proof

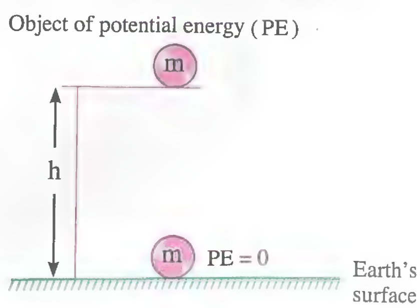
If an object of mass (m) is lifted up to a height (h), the work done (W) is determined by the relation : $W = F\,h$

Where (F) is the force required to lift the object up and equals its weight (w) :

$F = w = mg$ $\qquad\therefore W = mgh$

$\because$ The work done is stored in the form of potential energy (PE).

$\therefore$ $\boxed{PE = mgh}$



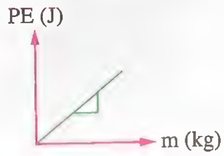
The factors that affect potential energy of an object :

1

The object's mass (m) :

Potential energy is directly proportional to the object's mass at constant height and free fall acceleration.

Slope $= \frac{\Delta PE}{\Delta m} = gh$



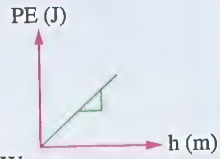
PE = mgh

2

The object's height (h) :

Potential energy is directly proportional to the object's height at constant mass and free fall acceleration.

Slope $= \frac{\Delta PE}{\Delta h} = mg = w$

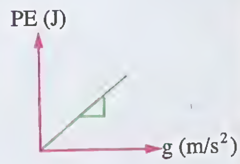


3

The free fall acceleration (g) :

Potential energy is directly proportional to the free fall acceleration at constant object's mass and height.

Slope $= \frac{\Delta PE}{\Delta g} = mh$



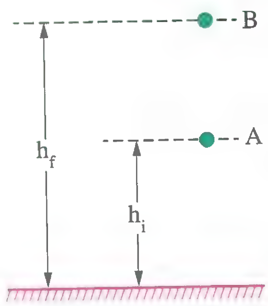
Note :

In the opposite figure, the work done to lift a body of mass (m) from the position (A) to the position (B) :

$W = mgh_f - mgh_i$

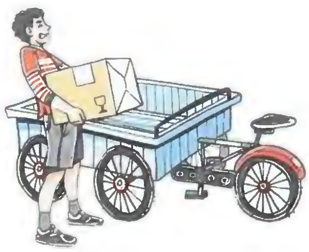
$= mg\,(h_f - h_i) = mg\Delta h$

i.e. $W = \Delta PE$

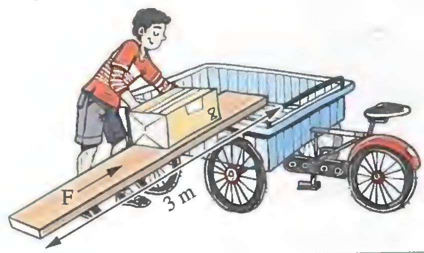


Life application

▶ When lifting a box of weight 450 N vertically upwards to a height of 1 m.



▶ When lifting the same box vertically upwards to a height of 1 m by using a ramp (inclined surface) of length 3 m.



The work done will be
$W = wh = 450 \times 1 = 450$ J

▶ This needs a force that is equivalent to the box's weight :

$F = \frac{W}{d} = \frac{450}{1} = 450$ N

▶ This needs a force that is less than the box's weight, but it needs larger displacement :

$F = \frac{W}{d} = \frac{450}{3} = 150$ N

Example 1

Two bodies x, y the mass of each is 10 kg, a person lifted the body (x) to a height of 1 m from the Earth's surface and lifted the body (y) to a height of 2.5 m from the Earth's surface, calculate :

(a) The change in the potential energy for each of the two bodies.

(b) The work done by the person on each of the two bodies and what do you conclude from that ? *(knowing that : $g = 10$ m/s^2)*

Solution

$m_x = 10$ kg | $m_y = 10$ kg | $h_x = 1$ m | $h_y = 2.5$ m | $g = 10$ m/s^2

$\Delta(PE)_x = ?$ | $\Delta(PE)_y = ?$ | $W_x = ?$ | $W_y = ?$

(a) $\Delta(PE)_x = m_x g \Delta h_x = 10 \times 10 \times (1 - 0) = 100$ J

$\Delta(PE)_y = m_y g \Delta h_y = 10 \times 10 \times (2.5 - 0) = 250$ J

(b) $W_x = Fd = m_x g h_x = 10 \times 10 \times 1 = 100$ J

$W_y = Fd = m_y g h_y = 10 \times 10 \times 2.5 = 250$ J

We conclude that the work done equals the change in the potential energy. ($W = \Delta PE$)

Example 2

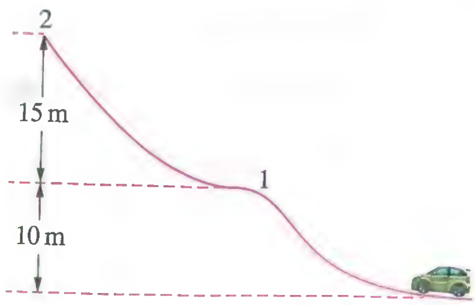
In the opposite figure, a small car of mass 200 kg is moved from the Earth's surface to position (1) then to position (2).

Calculate the work done and the change in the potential energy when the car moves from the Earth's surface to :

(a) position (1).

(b) position (2).

(knowing that : $g = 10$ m/s^2)



Solution

$m = 200$ kg | $g = 10$ m/s^2 | $h_1 = 10$ m | $h_2 = 25$ m | $W_1 = ?$

$\Delta(PE)_1 = ?$ | $W_2 = ?$ | $\Delta(PE)_2 = ?$

Clue

When the car moves from one position to another, so the work done = The change in the potential energy

$W = \Delta PE = mg\Delta h$

(a) When the car moves from the Earth's surface to the position (1) :

$W_1 = \Delta(PE)_1 = mg\Delta h_1 = 200 \times 10 \times (10 - 0) = 2 \times 10^4$ J

(b) When the car moves from the Earth's surface to the position (2) :

$W_2 = \Delta(PE)_2 = mg\Delta h_2 = 200 \times 10 \times (25 - 0) = 5 \times 10^4$ J

Example 3

A body (x) is placed at a height (h_x) from the Earth's surface, while body (y) is placed at height (h_y) from the Moon's surface if you know that the potential energies of the two bodies are equal and their masses are the same, calculate the ratio $\frac{h_x}{h_y}$. (knowing that the free fall acceleration on the Earth's surface is six times that on the Moon's surface)

Solution

$(PE)_x = (PE)_y$ | $m_x = m_y$ | $g_e = 6\,g_m$ | $\frac{h_x}{h_y} = ?$

$\because (PE)_x = (PE)_y$

$\therefore m_x g_e h_x = m_y g_m h_y$

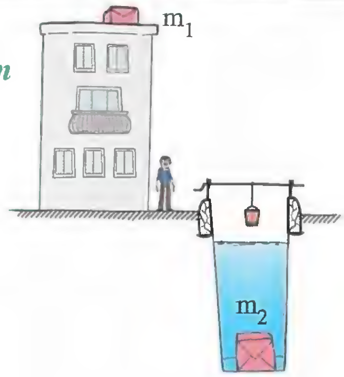
$\therefore 6\,g_m h_x = g_m h_y$

$\therefore \frac{h_x}{h_y} = \frac{1}{6}$

Example 4

A person stands on the surface of the Earth and there is next to him a building of height 10 m and a well of depth 10 m from the Earth's surface if a body of mass 2 kg is placed above the building and another body of mass 4 kg is placed at the bottom of the well, calculate the potential energy of the two bodies relative to the Earth's surface.

(knowing that : $g = 10\ m/s^2$)



Solution

$m_1 = 2\ kg$ | $h_1 = 10\ m$ | $m_2 = 4\ kg$ | $h_2 = -10\ m$ | $g = 10\ m/s^2$

$(PE)_1 = ?$ | $(PE)_2 = ?$

Clue

If the level of measurement is the level of the Earth's surface, so the sign of (h) is :

- ***Positive :*** *when the level of the body is higher than the level of the Earth's surface.*
- ***Negative :*** *when the level of the body is less than the level of the Earth's surface.*

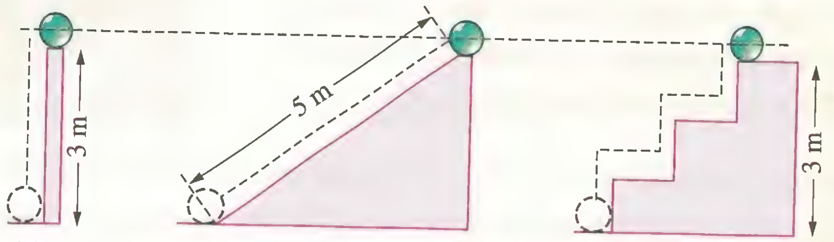
$(PE)_1 = m_1gh_1 = 2 \times 10 \times 10 = 200\ J$

$(PE)_2 = m_2gh_2 = 4 \times 10 \times (-10) = -400\ J$

2 Test yourself

Answered

Choose : The following figures represent three different frictionless paths that can be moved by a static ball placed on the ground to reach a certain height :



(a) (b) (c)

In which path, the work done to lift the ball is maximum ? .... **Explain your answer.**

ⓐ Path (a) ⓑ Path (b) ⓒ Path (c) ⓓ All are equal

....

....

⇒ **From the previous, we can compare between the kinetic energy and the potential energy as follows :**

Points of comparison	Kinetic energy	Potential energy
Definition :	The energy possessed by the object due to its motion.	The energy stored in the object due to its position or state.
Mathematical expression :	$KE = \frac{1}{2} mv^2$	$PE = mgh$
Affecting factors :	(1) Object's mass (m). (2) Object's velocity (v).	(1) Object's mass (m). (2) Height above the Earth's surface (h). (3) Free fall acceleration (g).
Unit of measurement :	The joule (J)	The joule (J)
Dimensions :	$ML^2 T^{-2}$	$ML^2 T^{-2}$

Note :

- The sum of kinetic energy and potential energy is called **mechanical energy**.

i.e. Mechanical energy = Kinetic energy + Potential energy

$$ME = KE + PE$$

Physics for the environment

- Most of the energy used by man comes from non-renewable resources such as :
  - Coal.
  - Petroleum.

- Non-renewable resources of energy are considered as unclean resources since they produce a lot of harmful products to the environment and man health.
- Because of this, there is a global trend, especially in the most industrialized countries, to use the renewable resources such as wind power and waterfalls as an energy resource to generate electricity and preserve the environment, as well.

QUESTIONS ON

Chapter 1

LESSON TWO

Energy

Interactive test

First Multiple choice questions

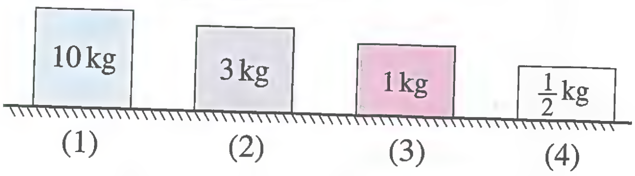
1 The dimensional formula of energy is ....

ⓐ $ML^{-1}T^{2}$ ⓑ $ML^{2}T^{-2}$ ⓒ $ML^{-1}T^{-2}$ ⓓ $M^{2}LT^{-1}$

2 An object of mass 2 kg is moving with uniform velocity and its kinetic energy is 25 J , then .... **(Choose two answers)**

ⓐ its velocity equals 100 m/s
ⓑ its velocity equals 12.5 m/s
ⓒ its velocity equals 5 m/s
ⓓ the work done on the object equals zero
ⓔ the work done on the object equals 25 J

3 In the opposite figure :



(i) If the four objects have the same speed, then the highest in kinetic energy is ....

ⓐ (1) ⓑ (2) ⓒ (3) ⓓ (4)

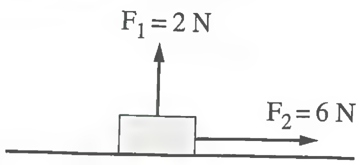
(ii) If the four objects have the same kinetic energy, then the highest in speed is ....

ⓐ (1) ⓑ (2) ⓒ (3) ⓓ (4)

4 The joule is .... **(Choose two answers)**

ⓐ the kinetic energy of a ball of mass 2 kg that moves with a velocity of 1 m/s
ⓑ the measuring unit of each of weight and force
ⓒ the work done by a horizontal force of 1 N to displace a body a horizontal displacement of 1 m
ⓓ equivalent to Newton/meter
ⓔ the measuring unit of each of work and momentum

5 The opposite figure represents two forces F_1 , F_2 that act on a static object to move it horizontally a distance of 4 m, so the change in the kinetic energy of the object is ....



ⓐ 8 J ⓑ 10 J ⓒ 24 J ⓓ 32 J

6 The kinetic energy of an object is 4 J. What is its kinetic energy if its speed is doubled ? ....

ⓐ 0.8 J ⓑ 4 J ⓒ 16 J ⓓ 8 J

7. If the velocity of an object is doubled and its mass decreases to its quarter. So, its kinetic energy ....

(a) decreases to its half
(b) remains constant
(c) decreases to its quarter
(d) is doubled

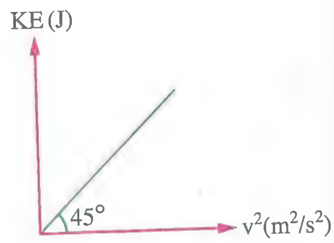
8. When the speed of a car is doubled, its kinetic energy ....

(a) is halved
(b) is doubled
(c) increases 4 times
(d) remains constant

9. Two objects, the mass of the first is double that of the second and the velocity of the first is half that of the second. So, the kinetic energy of the first is .... that of the second.

(a) half
(b) double
(c) quarter
(d) 4 times

10. The opposite graph represents the relation between the kinetic energy (KE) of a body of mass (m) and the square of its velocity (v^2), then the ....
(Choose two answers)
(knowing that : $g = 10\ m/s^2$, the two axes are drawn by the same scale)



(a) mass of the body equals 0.5 kg
(b) mass of the body equals 1 kg
(c) mass of the body equals 2 kg
(d) weight of the body equals 0.05 N
(e) weight of the body equals 20 N

11. Two bodies a , b the mass of a is 4 times that of b , if the two bodies have the same kinetic energy, then the ratio between their linear momentums $\left(\frac{P_a}{P_b}\right)$ is ....

(a) $\frac{1}{2}$
(b) $\frac{2}{1}$
(c) $\frac{1}{4}$
(d) $\frac{4}{1}$

12. A ball of mass (m) is moving horizontally with velocity (v) where it collides with a wall and rebounds by half its velocity, so the energy lost due to the collision equals ....

(a) $\frac{1}{8}\ mv^2$
(b) $\frac{3}{8}\ mv^2$
(c) $\frac{1}{4}\ mv^2$
(d) $\frac{1}{2}\ mv^2$

13. Two bodies x and y have the same mass, if $(KE)_x = 4\ (KE)_y$, then the momentum of x equals ....

(a) P_y
(b) $2\ P_y$
(c) $4\ P_y$
(d) $8\ P_y$

14. A particle rotates in a uniform circular path of radius 20 cm where a centripetal force of 10 N acts on it, so the particle's kinetic energy is ....

(a) 0.1 J
(b) 0.2 J
(c) 2 J
(d) 1 J

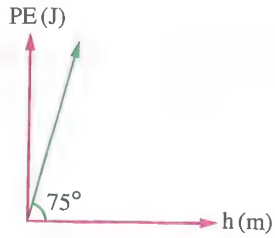
15. The stored energy in a compressed spring is ....

(a) kinetic energy
(b) potential energy
(c) nuclear energy
(d) repulsion energy

16 The opposite figure shows a book of mass 2 kg that is placed on a table, so the potential energy of the book equals .... (knowing that : $g = 9.8\ m/s^2$)

ⓐ 98 J ⓑ 10 J
ⓒ 2.5 J ⓓ 9.8 J

17 The opposite graph represents the relation between the potential energy of a body (PE) and its height (h) from the Earth's surface, then the .... **(Choose two answers)**
(knowing that : $g = 9.8\ m/s^2$, the two axes are drawn by the same scale)

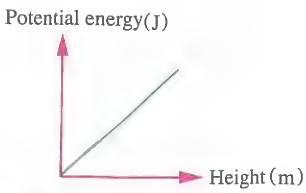


ⓐ slope of the line represents the mass of the body
ⓑ slope of the line represents the weight of the body
ⓒ slope of the line represents the velocity of the body
ⓓ mass of the body equals 0.4 kg
ⓔ mass of the body equals 3.7 kg

18 The potential energy of an object of mass 1 kg at the surface of the Earth equals ....
ⓐ 98 J ⓑ 9.8 J ⓒ 1 J ⓓ zero

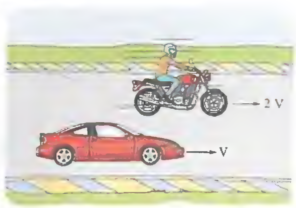
19 A man went to his apartment twice; once by using the stairs and another time by using the elevator. Which statement is correct ? ....
ⓐ The man possesses more potential energy when using the stairs
ⓑ The man possesses more potential energy when using the elevator
ⓒ The man has no potential energy when using the elevator
ⓓ The man possesses the same potential energy in both cases

20 The slope of the straight line in the opposite graph represents the ....



ⓐ object's mass ⓑ object's weight
ⓒ object's displacement ⓓ object's speed

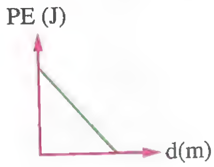
21 The opposite figure represents a car of mass m that moves with velocity v and a motorcycle of mass $\frac{m}{4}$ that moves with velocity 2 v, so the ratio between their kinetic energies $\left(\frac{(KE)_{car}}{(KE)_{motorcycle}}\right)$ is ....



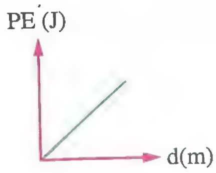
ⓐ $\frac{1}{2}$ ⓑ $\frac{1}{1}$ ⓒ $\frac{1}{4}$ ⓓ $\frac{2}{1}$

22 The graphical relation that represents the relation between the potential energy (PE) of a body falling freely and its distance from its original position (d) is ....

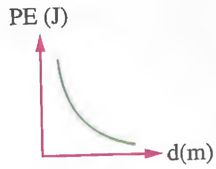
(a)



(b)



(c)



(d)

---

23 A bullet penetrates a wooden block and loses half its velocity. What is the ratio between the initial kinetic energy of the bullet and the kinetic energy of the bullet when it leaves the block ? ....

(a) 1 : 2 (b) 1 : 4 (c) 2 : 1 (d) 4 : 1

---

24 A 4 kg cart has a linear momentum with a magnitude of 20 kg.m/s. What is the cart's kinetic energy ? ....

(a) 20 J (b) 30 J (c) 50 J (d) 100 J

Second Essay questions

1 **Explain the following sentences :**

(1) The kinetic energy is a scalar quantity.

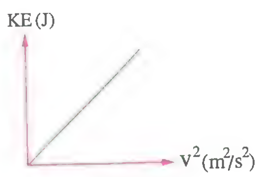
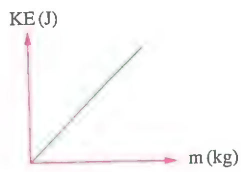
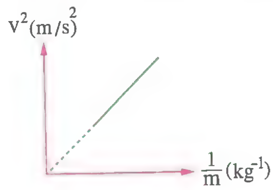
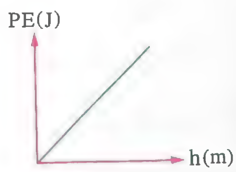
(2) The kinetic energy of a static body equals zero.

(3) The potential energy of an object increases when projected vertically upwards.

(4) The water at the top of a waterfall has a greater potential energy than the water at the bottom of the waterfall.

---

2 **Write down the mathematical relation and the slope of each graph :**

			
(1)	(2)	(3)	(4)

Where : (KE) is the kinetic energy, (v) is velocity of body, (m) is the mass of body, (PE) is the potential energy and (h) is the height.

---

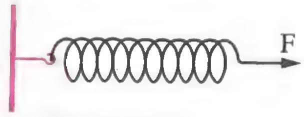
3 **In which figure (a) or (b) the person has the largest potential energy ? Explain your answer.**

(a)

(b)

4. **What is the difference between** the elastic potential energy and the gravitational potential energy ?

5. The opposite figure shows a spring that is elongated by force F, **what happens when** this force vanishes ? **Explain why ?**



6. **Complete the following tables (knowing that : g = 10 m/s^2) :**

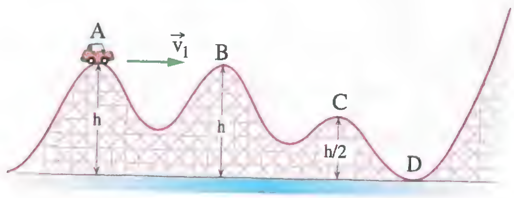
(1)

The mass (m)	The velocity (v)	The kinetic energy of the body (KE)
50 kg	10 m/s	.... 1 ....
.... 2	18 km/h	1 J
400 kg	.... 3	5000 J

(2)

The mass (m)	The height of the body from the Earth's surface (h)	The potential of the body (PE)
50 kg	.... 1	zero
.... 2	0.01 km	2500 J
7 kg	5 m	.... 3 ....
200 g	.... 4	2 J

7. The opposite figure shows a frictionless car of mass m in an amusement park that passes by point A with a linear velocity v_1, **what** is the work done by the gravitational force on the car to move it from point A to :



(a) point B.　　(b) point C.

Third Problems

1. **Find** the kinetic energy of a car of mass 2000 kg that is moving at a speed of 60 km/h.

(2.78×10^5 J)

2. A runner of mass 72 kg has the same kinetic energy of a car of mass 1200 kg that moves at a velocity of 2 km/h. **Find** the velocity of the runner.

(2.27 m/s)

3. In an experiment for measuring the kinetic energy using air track, the following results were obtained :

$\frac{1}{m}$ (kg^{-1})	2	3	4	5	8
v^2 $(m/s)^2$	4	6	x	10	16

(a) **Draw a graph** relating ($\frac{1}{m}$) on the x-axis and (v^2) on the y-axis.

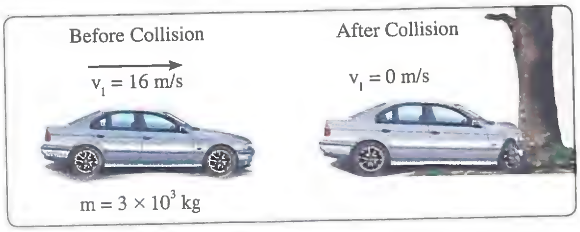
(b) **From the graph calculate :**

1- The value of x.

2- The kinetic energy. *($8\ m^2/s^2$, 1 J)*

4. An object of mass 12 kg starts its motion from rest with uniform acceleration of 10 m/s^2. **Calculate** its velocity and its kinetic energy after covering a distance of 80 m. *(40 m/s, 9600 J)*

5. A car of mass 3×10^3 kg and velocity 16 m/s crashed into a tree. The tree stayed still and the car stopped as illustrated in the figure below.



(a) **What** is the change in the kinetic energy of the car?

(b) **What** is the work done on the tree when the car crashed into it ?

(c) **Find** the magnitude of the force acting on the car's front when it is deformed by 50 cm. *(-3.84×10^5 J, 0, 7.68×10^5 N)*

6. A force of 36 N is acting on an object of mass 25 kg in a direction that makes an angle of 60° with the horizontal. **Calculate** the velocity of the object after covering a horizontal distance of 100 m if it started its motion from rest. *(12 m/s)*

7. The kinetic energy of an object is 36 J and its momentum is 18 kg.m/s , **calculate :**

(a) The velocity of the object. (b) The mass of the object. *(4 m/s , 4.5 kg)*

8. A machine gun fires 600 bullets per minute. If the mass of one bullet is 49 g and its velocity is 200 m/s, **find** the kinetic energy generated per second. *(9800 J)*

9. A bullet of mass 10 g was fired with a velocity of 600 m/s towards a rubber block of thickness 8 cm, when the bullet came out of the rubber block its velocity was 400 m/s, **find :**

(a) The work done by the resistance of the rubber on the bullet.

(b) The average resistance of the rubber block to the bullet. *(–1000 J, –12500 N)*

10 **What** is the change in kinetic energy when a 50 g ball hits the pavement with a velocity of 6 m/s and rebounds with a velocity of 10 m/s ? *(1.6 J)*

11 An athlete of weight 700 N has climbed a mountain to a height of 200 m from the ground. **Find** the work done by him. *(14×10^4 J)*

12 **Calculate** the mass of an object on the Earth's surface if its potential energy at a height of 5 m above the Earth's surface equals 980 J and the acceleration due to gravity = 9.8 m/s^2 *(20 kg)*

13 The following table shows the relation between the potential energy (PE) and height (h) from the ground :

PE (J)	16	32	48	64	80
h (m)	2	4	6	8	10

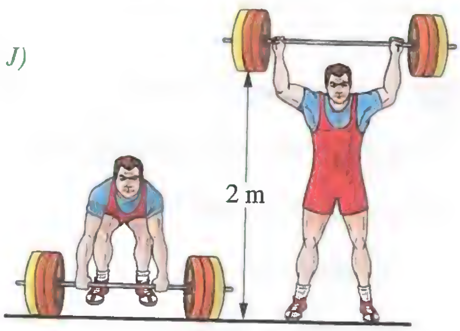
(a) **Draw a graph** relating (PE) on the y-axis and (h) on the x-axis.

(b) **From the graph find :**

1- The object's potential energy at height 7 m.

2- The mass of the object if g = 9.8 m/s^2 *(56 J , 0.816 kg)*

14 If the mass of the load is 100 kg, **find** the work done by the weight lifter. (where : g = 10 m/s^2) *(2000 J)*

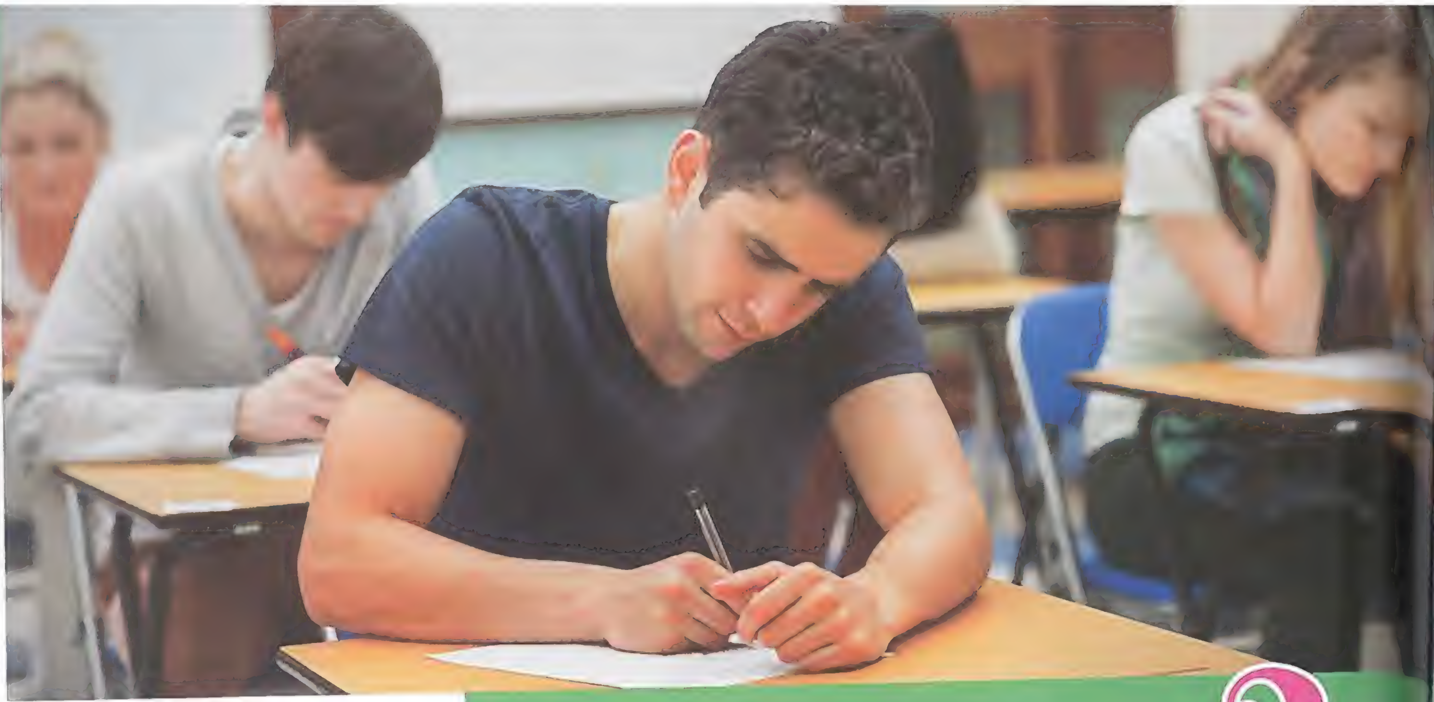


15 Two boxes (A) , (B) of weights 40 N and 60 N respectively, the box (A) is on the ground, while the box (B) is at a height of 2 m above the ground. **At what** height should the box (A) be lifted to have the same potential energy of the box (B) ? *(3 m)*

16 A 78 kg skydiver has a speed of 62 m/s at an altitude of 870 m above the ground.

(a) **Determine** the kinetic energy possessed by the skydiver.

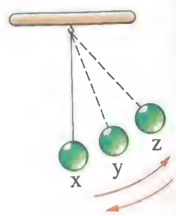
(b) **Determine** the potential energy possessed by the skydiver. *(1.5×10^5 J , 6.79×10^5 J)*



MODEL EXAM ON

Chapter 1 Work and Energy

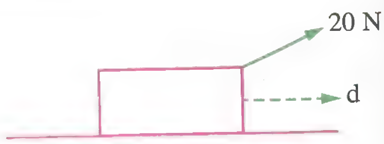
First Choose the correct answer



1. The maximum potential energy of the pendulum is at point ....

ⓐ x   ⓑ y
ⓒ z   ⓓ no correct answer

2. In the opposite figure :



If the body moves a displacement of 2 m on a frictionless surface, the work done on it will be ....

ⓐ more than 40 J   ⓑ less than 40 J
ⓒ equal to 40 J   ⓓ 80 J

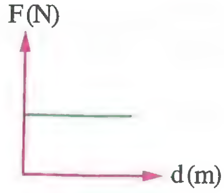
3. The work done on a body is negative when the force acting on it is .... direction of the displacement.

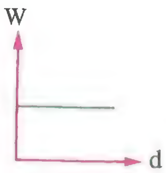
ⓐ in the same   ⓑ opposite to the
ⓒ perpendicular to the   ⓓ no correct answer

4. When the velocity of a car is doubled , its kinetic energy will ....

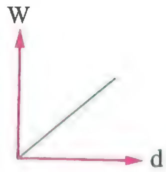
ⓐ decrease to its half   ⓑ be doubled
ⓒ increase 4 times   ⓓ remain constant

5. The opposite figure represents the relation between the acting force on a body and its displacement, so the relation between the work done and the displacement is ....

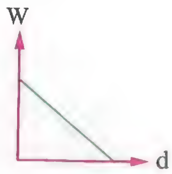




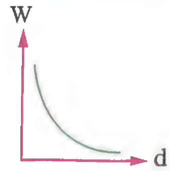
ⓐ



ⓑ



ⓒ



ⓓ

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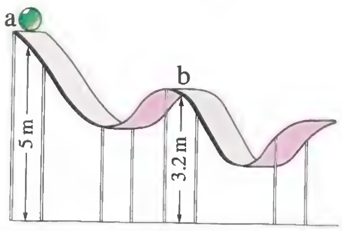
6. A car of mass 1000 kg is moving with constant velocity for a distance of 100 m on an inclined road that inclines on the horizontal at 30°, then the change in the potential energy of the car at the bottom of the inclined road is .... ($g = 9.8\ m/s^2$)

ⓐ 4.9×10^5 J ⓑ 5.8×10^5 J ⓒ 6.7×10^5 J ⓓ 8.6×10^5 J

---

7. In the opposite figure :

A ball slides from rest at point (a) through a path of negligible friction, so the velocity of the ball at point (b) equals .... ($g = 10\ m/s^2$)



ⓐ 4 m/s ⓑ 5 m/s

ⓒ 6 m/s ⓓ 7.5 m/s

---

8. If the weight of a body on the surface of the Earth is 6 times its weight on the surface of the Moon, then the ratio between its kinetic energy on the Earth and its kinetic energy on the Moon when it moves with the same velocity equals ....

ⓐ $\frac{1}{6}$ ⓑ $\frac{1}{1}$ ⓒ $\frac{6}{1}$ ⓓ $\frac{36}{1}$

---

9. If the kinetic energy of a ball is decreased to $\frac{1}{3}$ of its value, so its velocity will be ....

ⓐ decreased to $\frac{1}{3}$ ⓑ decreased to $\frac{1}{9}$

ⓒ decreased to $\frac{1}{\sqrt{3}}$ ⓓ increased 3 times

---

10. Two identical balls A , B are thrown from the same height, where A is projected with velocity v and B is left to fall freely, then at the instant of touching the ground ....

ⓐ $(KE)_A = (KE)_B \neq 0$ ⓑ $(KE)_A > (KE)_B$

ⓒ $(KE)_A < (KE)_B$ ⓓ $(KE)_A = (KE)_B = 0$

Second Answer the following questions

11 Two bodies of mass 1 g and 4 g respectively if they have the same kinetic energy, **calculate** the ratio between the linear momentum of body (A) to that of body (B).

....

....

....

....

....

12 A worker does a work of 360 J against a friction force of 20 N while pulling a wheat bag on the ground with a uniform velocity for 4.5 s. **Find** the value of the velocity by which the bag moves.

....

....

....

....

13 According to Bohr's model for the structure of atom, the electron rotates around the nucleus in a uniform circular orbit, **explain why** the centripetal force does no work on the electron during its rotation.

....

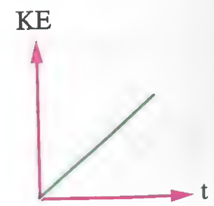
....

14 If the potential energy of a body of mass 15 kg that is placed at height (h) from the ground equals 1200 J, **calculate** the value of (h). ($g = 10\ m/s^2$)

....

....

15 The opposite graph represents the change of the kinetic energy of a body of mass (m) with the time (t). **Is** the body moving with uniform acceleration ?



....

....

16 A student projects a stone vertically upwards to reach a height of 12 m. If he projects it with the same velocity on the surface of the Moon, **calculate** the height that can be reached by the stone by using the equations of work and the energy.
(knowing that : the free fall acceleration on the surface of the Moon = $\frac{1}{6}$ of the free fall acceleration on the surface of the Earth)

....
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....
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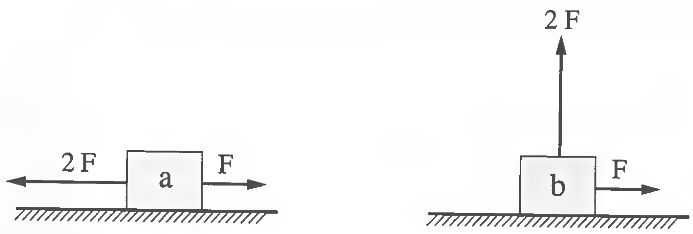
....

17 The next two figures shows two identical bodies a , b that are placed on a horizontal surface. Forces F , 2 F act on each of them for time (t) to displace each of them a displacement (d) in the horizontal direction. **Which** of the two bodies has the largest work done on it ?



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Chapter 2 Law of Conservation of Energy

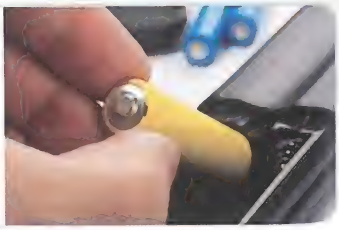
We have studied in the previous chapter that energy is the capacity to do work and there are different forms of energy that can be converted into one another, such as :

1. **Potential energy** converts to Kinetic energy in a waterfall.

2. **Chemical potential energy stored in coal, gasoline and other types of fuel** converts to Thermal energy then to mechanical work that is used by means of transportation such as cars and trains.

3. **Electrical energy in the electric bulb** converts to Thermal and light energies.

4. **Chemical potential energy stored in a battery** converts to Electrical energy when the battery is connected to a closed electric circuit.



5 **Chemical potential energy stored in the wood** converts to Thermal and light energies at burning.

- On converting energy from one form into another, the amount of energy remains constant and this is known as **the law of conservation of energy**.

Law of conservation of energy :

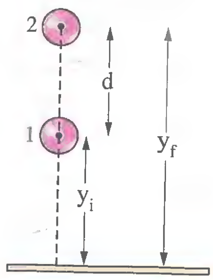
"Energy is neither created nor destroyed, but it can be converted from one form into another."

Through the following, we will study one of the forms of the law of conservation of energy which is the law of conservation of mechanical energy.

Law of conservation of mechanical energy

Proof

Assume that an object of mass (m) is projected vertically upwards from point (1) at initial velocity (v_i) to reach point (2) at final velocity (v_f), the work done by the gravitational force on the object while rising leads to :



1. **An increase in the potential energy of the object by increasing the height.**
2. **A decrease in the kinetic energy of the object due to a decrease in its velocity.**

According to the third equation of motion : $v_f^2 - v_i^2 = 2\ ad$

Since the object moves upwards against gravity, it decelerates uniformly.

$\therefore a = -g$

$\therefore v_f^2 - v_i^2 = 2\,(-g)\,d$

Multiply the previous equation by $(\frac{1}{2}\ m)$:

$\frac{1}{2}\ m\,(v_f^2 - v_i^2) = -mgd$

$\because d = y_f - y_i$

$\therefore \frac{1}{2}\ m\,(v_f^2 - v_i^2) = -mg\,(y_f - y_i)$

$\frac{1}{2}\ mv_f^2 - \frac{1}{2}\ mv_i^2 = -mgy_f + mgy_i$

$mgy_f + \frac{1}{2}\ mv_f^2 = mgy_i + \frac{1}{2}\ mv_i^2$

$\therefore \boxed{PE_f + KE_f = PE_i + KE_i}$

This means that :

The sum of potential energy and kinetic energy at point (1) equals the sum of potential energy and kinetic energy at point (2).

Conclusion :

1. The sum of potential energy and kinetic energy of an object at any point on its path under the effect of gravity only is constant.
2. The increase in the kinetic energy of a falling object will be on the expense of its potential energy *i.e.* Potential energy decreases and vice versa.

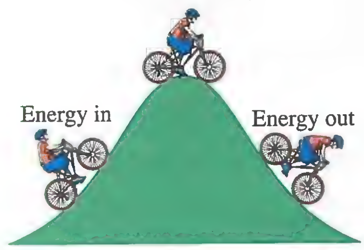
From the previous, we can define the mechanical energy and the law of conservation of mechanical energy as follows :

The mechanical energy :

It is the sum of potential energy and kinetic energy of an object.

Law of conservation of mechanical energy :

"The sum of potential energy and kinetic energy of an object at any point on its path under the effect of gravity only is constant".



Mechanical energy (ME) = PE + KE

Notes :

- **When an object moves vertically under the effect of the acceleration due to gravity, then :**
  - At the maximum height :

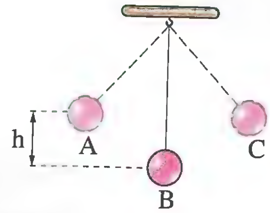
    $\because$ v = 0 $\quad\quad$ $\therefore$ KE = 0 $\quad\quad$ $\therefore$ ME = PE
  - At the mid-distance between the ground and the maximum height :

    KE = PE $\quad\quad$ $\therefore$ ME = 2 KE = 2 PE
  - At the moment , the object touches the ground :

    $\because$ h = 0 $\quad\quad$ $\therefore$ PE = 0 $\quad\quad$ $\therefore$ ME = KE

    So : $PE_{\text{at maximum height}} = KE_{\text{at the ground}}$
- **In case of a simple pendulum as in the figure :**
  - The position (B) is called the equilibrium position at which the velocity of the pendulum ball is maximum.

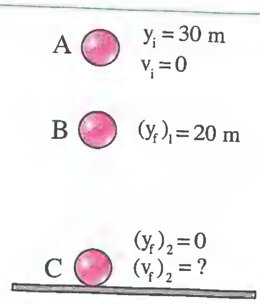
- At the two positions (C) and (A), the ball makes its maximum displacement away from position (B) and the velocity of the ball at them equals zero and also its kinetic energy so at these positions the mechanical energy of the ball equals the potential energy.



- The height (h) in the relation (PE = mgh) represents the vertical distance between the position of the pendulum ball at any point and the equilibrium position.

Example 1

In the opposite figure, a static object at a height of 30 m above the ground (at point A) has a potential energy of 1470 J. If this object falls neglecting the air resistance and considering $g = 9.8\ m/s^2$, find :



(a) The kinetic energy and potential energy of the object at a height of 20 m above the ground.

(b) The object's velocity at the instant of hitting the ground.

Solution

$y_i = 30$ m | $(PE)_i = 1470$ J | $v_i = 0$ | $(y_f)_1 = 20$ m | $(y_f)_2 = 0$

$g = 9.8\ m/s^2$ | $(PE_f)_1 = ?$ | $(KE_f)_1 = ?$ | $(v_f)_2 = ?$

(a) At point A :

$(PE)_i = mgy_i$

$1470 = m \times 9.8 \times 30$

$m = 5$ kg

$(PE_f)_1 = mg(y_f)_1 = 5 \times 9.8 \times 20 = 980$ J

By applying the law of conservation of mechanical energy on the points A and B :

$(PE_f)_1 + (KE_f)_1 = (PE)_i + (KE)_i$

$980 + (KE_f)_1 = 1470 + 0$, $(KE_f)_1 = 490$ J

(b) By applying the law of conservation of mechanical energy on the points A and C :

$(PE)_i + (KE)_i = (PE_f)_2 + (KE_f)_2$

$1470 + 0 = 0 + \left(\frac{1}{2} \times 5 \times (v_f)_2^2\right)$ $(v_f)_2 = 24.25$ m/s

Example 2

An object of mass 0.5 kg falls freely from a point at a height of 100 m from the Earth's surface. Find :

(a) The potential and kinetic energies at the top.

(b) The potential and kinetic energies at the ground.

(c) The velocity of the object on touching the ground. (where : $g = 10\ m/s^2$)

Solution

$m = 0.5\ kg$ | $h = 100\ m$ | $g = 10\ m/s^2$ | $PE = ?$ | $KE = ?$ | $v_f = ?$

(a) $PE = mgh = 0.5 \times 10 \times 100 = 500\ J$, $KE = 0$

(b) $PE = 0$, $KE = PE$ (at the top) $= 500\ J$

(c) $KE = \frac{1}{2} mv_f^2$, $500 = \frac{1}{2} \times 0.5 \times v_f^2$

$v_f = 44.72\ m/s$

Example 3

An object falls freely from a point 5 m high. What is the velocity by which the object reaches the ground ? (where : $g = 10\ m/s^2$)

Solution

$h = 5\ m$ | $g = 10\ m/s^2$ | $v_i = 0$ | $v_f = ?$

$PE_1 + KE_1$ (at maximum height) $= PE_2 + KE_2$ (at the ground)

$mgh + 0 = 0 + \frac{1}{2} mv_f^2$

$v_f = \sqrt{2gh} = \sqrt{2 \times 10 \times 5} = 10\ m/s$

Example 4

An object is projected from the ground vertically upwards at velocity 10 m/s. Find the maximum height reached by the object using the equations of work and the energy. (where : $g = 10\ m/s^2$)

Solution

$v_i = 10$ m/s $g = 10$ m/s^2 $h = ?$

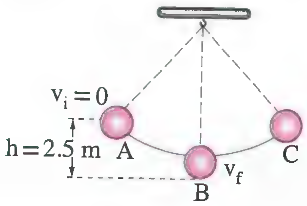
$(KE)_{\text{at the Earth's surface}} = (PE)_{\text{at the maximum height}}$

$\frac{1}{2} mv_i^2 = mgh$

$\frac{1}{2} \times 10^2 = 10\ h$ $\therefore h = 5$ m

Example 5

The diagram illustrates a ball hung by a thread that swings in a certain plane. If the ball's mass is 4 kg and g = 9.8 m/s², find the maximum velocity that can be reached by the ball during oscillation, neglecting the air resistance.



Solution

$m = 4$ kg $g = 9.8$ m/s^2 $v_i = 0$ $h = 2.5$ m $v_{max} = ?$

The greatest velocity of the ball during oscillation is at the point (B).

By applying the law of conservation of mechanical energy at the points A and B :

$(PE)_A + (KE)_A = (PE)_B + (KE)_B$

$mgh + 0 = 0 + \frac{1}{2} mv_B^2$

$gh = \frac{1}{2} v_{max}^2$

$v_{max} = \sqrt{2gh} = \sqrt{2 \times 9.8 \times 2.5} = 7$ m/s

1 Test yourself

Answered

Is it possible for a ball falling freely from a certain height towards the surface of the Earth to bounce after its collision with the ground to a level above its original height ? **Explain your answer.**

....

....

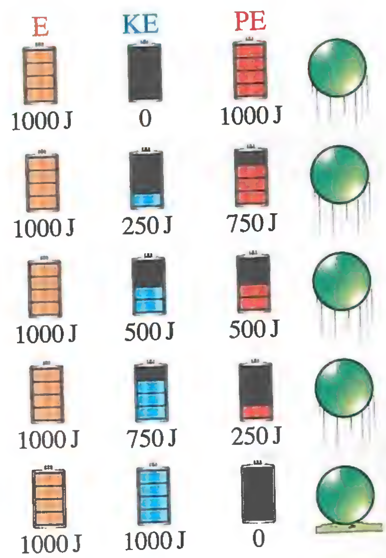
....

Law of conservation of energy in everyday life

There are many examples of mutual transformation between potential energy and kinetic energy, like :

EKB

1 Projecting an object upwards :



- When a ball is projected vertically upwards from the ground its potential energy equals zero at the ground, while its kinetic energy is maximum.
- As the ball rises, its potential energy increases gradually and its kinetic energy decreases by the same value.
- Potential energy reaches its maximum value at the highest point reached by the ball where its kinetic energy = zero
- When the ball starts to return back to the ground, its kinetic energy increases gradually, while its potential energy decreases.
- When the ball reaches the ground, the potential energy becomes zero at the ground while kinetic energy becomes maximum.

2 The roller coaster :

- Where the cart acquires the maximum potential energy at the top which is then converted into kinetic energy on falling.

3 In pole vault :

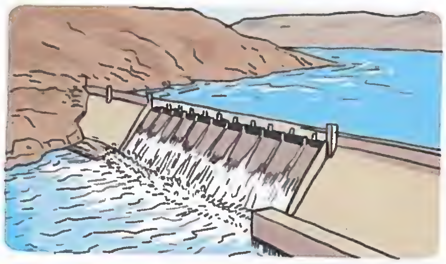
- Where the potential energy is stored in the pole during the jump and then converted into kinetic energy.

4 When shooting arrows :

Where potential energy is stored in the stretched string and then converted into kinetic energy when the string is released.

5 The stagnant water behind the dam :

Where the water stores potential energy which is converted into kinetic energy when the water start falls through the dam.



Practical Experiment

Law of conservation of energy.

1. Experiment Objective :

- Verifying the law of conservation of mechanical energy.

2. Tools :

- A tennis ball.
- Digital scale.
- Sticker tape.
- Stopwatch.
- Tape.

3. Procedure :

1. Measure the mass of the tennis ball in grams using the digital balance and convert it into kilograms.
2. Stick pieces of the sticker tape on the wall at different heights (1 m , 2 m , 2.5 m ... etc.)
3. Drop the tennis ball from the first height (1 m) and measure the time taken to reach the ground.
4. Repeat the previous step several times and find the average time.
5. Repeat the previous steps (3) and (4) for the different premeasured heights (2 m, 2.5 m ... etc.) and record the obtained results in the following table :

Height (h) m	Time (t) s			
	First trial	Second trial	Third trial	Average value
1 m				
2 m				
2.5 m				

6. Find the potential energy (PE) of the ball at each height by using the relation :

   PE = mgh (given that : $g = 9.8\ m/s^2$)

7. Find the final velocity (v_f) of the ball at the instant of hitting the ground by using the relation :

   $v_f = v_i + gt$ (since the ball has fallen from rest, then $v_i = 0$)

8. Find the kinetic energy (KE) of the ball at the instant of hitting the ground using the relation : $KE = \frac{1}{2} mv_f^2$

Record the results in the following table :

Height above ground (h)	1 m	2 m	2.5 m
Potential energy (PE) at that height			
Kinetic energy (KE) just before hitting the ground			

4. Conclusion :

1. By increasing height, the potential energy increases.
2. Potential energy$_{\text{at maximum height}}$ = Kinetic energy$_{\text{at the ground}}$ = Mechanical energy

   i.e. Mechanical energy = Potential energy + Kinetic energy = constant

2 Test yourself

Answered

Which of the two arrows goes faster at the moment of its launch? **Explain your answer.**

(1)

(2)

....

....

....

QUESTIONS ON

Chapter 2

Law of Conservation of Energy

Interactive test

First Multiple choice questions

1. When an object is projected vertically upwards, which of the following physical quantities will equal zero at the maximum height ? ....

ⓐ The gravitational force
ⓑ The acceleration
ⓒ The potential energy
ⓓ The velocity

2. When an object is thrown upwards ....

ⓐ KE increases and PE decreases
ⓑ KE decreases and PE increases
ⓒ both PE and KE increase
ⓓ both PE and KE decrease

3. When an object falls freely, then its .... during falling. **(Choose two answers)**

ⓐ mechanical energy increases
ⓑ mechanical energy decreases
ⓒ mechanical energy remains constant
ⓓ potential energy decreases and its kinetic energy increases
ⓔ potential energy increases and its kinetic energy decreases

4. When an object is thrown vertically upwards, its mechanical energy will ....

ⓐ increase
ⓑ decrease
ⓒ be constant at any point
ⓓ no correct answer

5. The ratio between the mechanical energy of an object that is projected vertically upwards and its potential energy at maximum height is ....

ⓐ $\frac{2}{1}$
ⓑ $\frac{1}{2}$
ⓒ $\frac{1}{1}$
ⓓ $\frac{1}{4}$

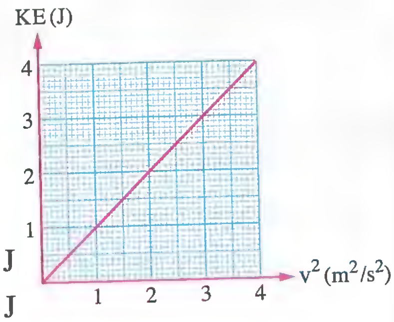
6. An object of mass (m) falls freely from a certain height. If velocity at the mid-distance between its initial position and the ground, then its mechanical energy = ...

ⓐ $\frac{1}{4}$ mv^2
ⓑ $\frac{1}{2}$ mv^2
ⓒ mv^2
ⓓ $2\ mv^2$

7. An object of mass 12 kg is falling freely from a certain height, if its mechanical energy at the mid-distance between its initial position and the ground is 150 J, then its speed at the instant of touching the ground = ... m/s

ⓐ 50
ⓑ 25
ⓒ 5
ⓓ 20

8 A body falls from a height of 18 m from the Earth's surface and the opposite graph represents the relation between the kinetic energy of the body (KE) and the square of its velocity (v^2) during falling, so the .... **(Choose two answers)**

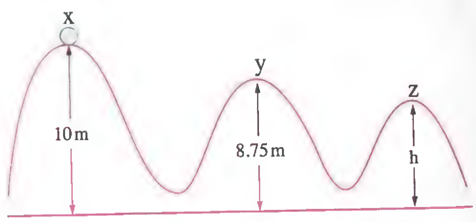


(a) mass of the body = 1 kg and the mechanical energy = 180 J
(b) mass of the body = 2 kg and the mechanical energy = 360 J
(c) potential energy of the body at height of 4 m equals 360 J
(d) kinetic energy of the body at height of 10 m equals 160 J
(e) kinetic energy of the body at height of 12 m equals 180 J

9 An object of mass 5 kg falls from a height of 10 m from the Earth's surface, then the .... ($g = 10\ m/s^2$) **(Choose two answers)**

(a) kinetic energy of the object at height of 10 m = The mechanical energy of the object
(b) potential energy of the object at the Earth's surface = The mechanical energy of the object
(c) kinetic energy of the object at height 5 m = Half the value of the mechanical energy of the object
(d) kinetic energy of the object at height 3 m = The potential energy of the object at height 7 m
(e) kinetic energy of the object at height 4 m = Double the potential energy of the object at height 6 m

10 In the opposite figure :
A static body of mass 1 kg slides on a smooth curved path starting from point x, then :



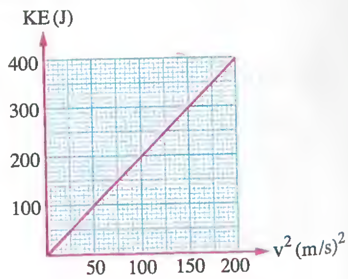
(i) The velocity of the body at point y equals ....

(a) 3 m/s (b) 5 m/s (c) 6 m/s (d) 6.5 m/s

(ii) If the body reaches point z with velocity 7 m/s, then the height of point z from the ground equals .... (where : $g = 10\ m/s^2$)

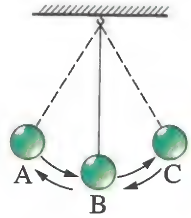
(a) 8.45 m (b) 7.55 m (c) 7.25 m (d) 6.85 m

11 The opposite graph shows the relation between the kinetic energy that falls from a height of 10 m above the ground and the square of its velocity (v^2) during falling, so its potential energy at a height of 2 m equals .... ($g = 10\ m/s^2$)



(a) 20 J (b) 40 J
(c) 60 J (d) 80 J

12 The opposite figure shows a simple pendulum that swings, then ....



ⓐ KE at C is maximum

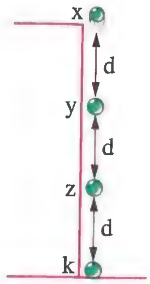
ⓑ the mechanical energy at A > the mechanical energy at B

ⓒ PE at A is maximum

ⓓ PE at C > PE at A

---

13 The opposite figure shows a body that falls from the top of a building of height 3 d, then .... **(Choose two answers)**



ⓐ PE at x = KE at y

ⓑ PE at y > KE at k

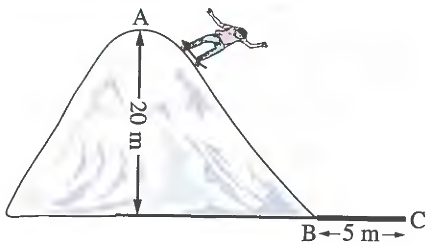
ⓒ KE at z = PE at y

ⓓ PE at x > KE at k

ⓔ KE at z > PE at k

---

14 The opposite figure shows the path of a skater of mass 80 kg that skates from rest from the top of a hill at a height 20 m from the ground. If the path from point A to point B is smooth and the path from point B to point C is rough , then the average friction force required to stop the skater at point C is .... (where : $g = 10\ m/s^2$)



ⓐ –1600 N ⓑ –2400 N ⓒ –3200 N ⓓ –4000 N

Second Essay questions

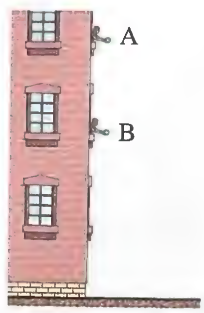
1 A ball slides from the top of an inclined frictionless surface. **Will** its kinetic energy increase during its sliding ? **Explain your answer.**

---

2 When an engineer designs the path of an amusement train in the amusement park, he designs the first hill to be higher than the other hills. **Explain why ?**

---

3 From the opposite figure, if B leaves a ball to fall from the second floor while A leaves a ball to fall from the third floor where the two balls fall freely towards the ground. **Which** ball of them will reach the ground with greater velocity ? **Explain your answer** concerning the definitions of potential energy and kinetic energy.



4 An object of mass 4 kg falls freely from a height of 20 m above the ground. **Fill in** the blank cells in the following table, neglecting the air resistance given that ($g = 10\ m/s^2$) :

Point	Displacement from the starting point (m)	Potential energy (J)	Object's velocity (m/s)	Kinetic energy (J)	Mechanical energy (J)
(1)	0	....	....	....	....
(2)	....	....	5	....	....
(3)	....	400	....	....	....
(4)	....	....	....	800	....

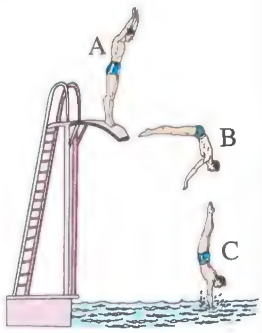
From the results you obtained, during falling define the point at which :

(a) The mechanical energy of the object equals its kinetic energy.

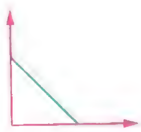
(b) The mechanical energy of the object equals its potential energy.

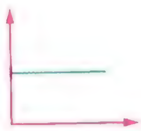
(c) The kinetic energy of the object equals its potential energy.

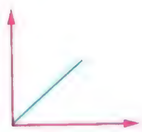
5 **In the opposite figure :**
At any position the kinetic energy of the man is maximum ?
Giving reasons.



6 A body has been projected vertically upwards. You have got three graphs (1 , 2 and 3); each of them expresses the relation between two physical quantities.


(1)


(2)


(3)

Decide which graph represents the relation between :

(a) Potential energy and the object's height above the ground.

(b) Kinetic energy and the object's height above the ground.

(c) The mechanical energy and the object's height above the ground.

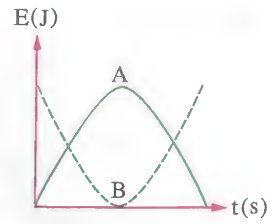
7 When an amusement car slides from the maximum height, its speed will gradually increase. **Explain why this happens.**

8 **The given graph shows the change in the kinetic and potential energies of a body as time passes :**

(a) **Does** this represent the motion of a body that is projected vertically upwards ? **Give reason for your answer.**

(b) By using your answer in (a) **which** curve represents the change of potential energy **and which** curve represents the change of kinetic energy ?

(c) **Add to** the graph a line that represents the mechanical energy of the body.

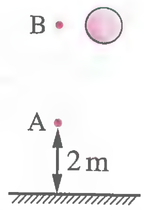


Third Problems

1 An object is thrown upwards with initial velocity 10 m/s. If its potential energy at maximum height is 1000 J, **find** its mass. *(20 kg)*

2 A ball of mass 200 g falls from a height of 100 m. **Calculate** the mechanical energy of the ball when it reaches half this height. (where : $g = 10\ m/s^2$) *(200 J)*

3 The opposite figure shows an object of mass 10 kg falling freely, if its mechanical energy at point B is 800 J, **calculate** its kinetic energy at point A. (where : $g = 10\ m/s^2$) *(600 J)*



4 A ball of mass 0.5 kg is projected vertically upwards. If its velocity at 4 m high is 3 m/s, **find** the work done to project the ball, given that acceleration due to gravity = $10\ m/s^2$ *(22.25 J)*

5 **Calculate** the work done by a worker to carry a sack of cement of mass 50 kg to a height of 20 m. If the sack falls from him to the ground, **find** its velocity when it reaches the ground. (where : $g = 9.8\ m/s^2$) *(9800 J, 19.8 m/s)*

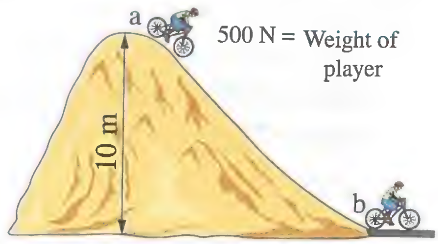
6 **Using the opposite diagram, find each of :**

(a) Potential energy of the bicycle rider at point (a).

(b) Potential energy of the bicycle rider at point (b).

(c) Mechanical energy of the bicycle rider at point (b).

(where : $g = 10\ m/s^2$) *(5000 J, 0, 5000 J)*



7 An object of mass 0.2 kg is projected vertically upwards by a velocity of 20 m/s, neglecting the air resistance, **calculate :**

(a) The maximum height reached by the object.

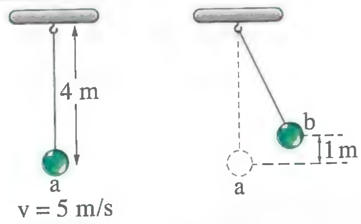
(b) The speed of the object at a height of 10 m from the ground.

(where : $g = 10\ m/s^2$) *(20 m , 14.14 m/s)*

8 An object of mass 1 kg is projected vertically upwards by a velocity of 24.5 m/s, **calculate** its potential energy when its speed becomes 4.9 m/s. (where : $g = 10\ m/s^2$) *(288 J)*

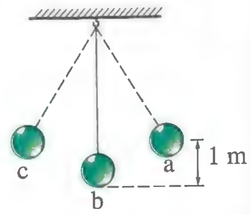
9 A ball of mass 0.5 kg falls from a height of 20 m, neglecting the air resistance, **calculate** its momentum just before it touches the ground.
(where : $g = 10\ m/s^2$) *(10 kg.m/s)*

10 By using two opposite figures, **calculate :**
(a) The velocity of the body at point (b).
(b) The maximum height reached by the body.
(where : $g = 9.8\ m/s^2$) *(2.32 m/s, 1.28 m)*

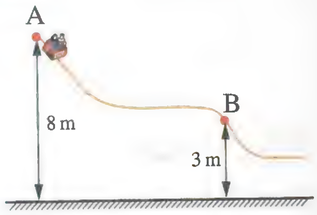


11 Two objects falls at the same instant where the mass of the first object is 3 times that of the second object and the first object falls from a height that is $\frac{1}{3}$ the height from which the second object falls.
Find the ratio between the kinetic energy of the first object and the kinetic energy of the second object at the instant of reaching ground. *($\frac{1}{1}$)*

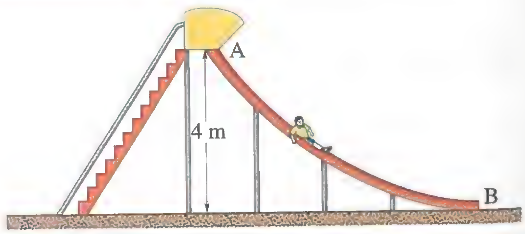
12 In the opposite figure a simple pendulum of mass 15 g starts its motion at point b and its speed reaches zero at points a , c. **Calculate** the maximum potential energy and the maximum kinetic energy if the acceleration due to gravity is $10\ m/s^2$. *(0.15 J , 0.15 J)*



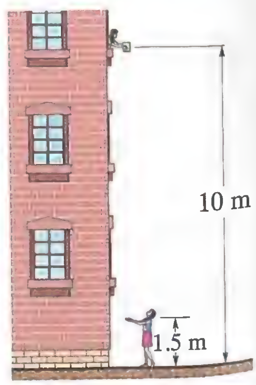
13 An amusement car starts its motion from rest at point A to move on a frictionless rails as shown in the opposite figure. **Calculate** the velocity of the car at point B. ($g = 10\ m/s^2$) *(10 m/s)*



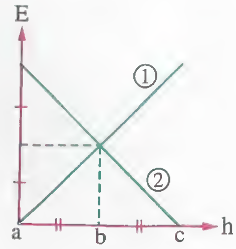
14 In the opposite figure a child of mass 25 kg slides down from rest at point A, if its speed at point B was 6 m/s, **calculate** the energy lost due to friction with the surface.
(where : $g = 9.8\ m/s^2$) *(530 J)*



15 In the opposite figure, a person left a book of mass 2 kg to fall freely from rest. Neglecting the resistance of air, **calculate :**
(a) The work done on the book by the gravitational force to reach the hands of the other person.
(b) The average force exerted by the hands of the other person on the book if the book lost its speed within 0.2 s when it reached the hands of the other person standing at the bottom of the building.
(where : $g = 10\ m/s^2$) *(170 J , –130.4 N)*



16 The opposite graph shows the change of the potential and kinetic energies for an object that is projected vertically upwards till it reaches the maximum height with the height (h) :



(a) **Which line** represents the change in KE and **which line** represents the change in PE?

(b) Assuming that the maximum height of the object is 20 m and its mass is 10 kg and $g = 10 \text{ m/s}^2$, **determine** the values of KE and PE at the heights a , b and c with **determining** these heights.

(c) **Calculate :**

1- The object velocity at a , b and c.

2- The mechanical energy of the object.

(2000 J, 0, 0, 1000 J, 1000 J, 10 m, 0, 2000 J, 20 m, 20 m/s, 14.14 m/s, 0, 2000 J)

---

17 An object is projected vertically upwards from the surface of the ground where its velocity reaches zero at a height of 8 m and the following table demonstrates the relation between the potential energy of the body and its height from the surface of the Earth :

PE (J)	30	a	90	150	180	210	240
h (m)	1	2	3	b	6	7	8

(a) **Draw the graphical** relation between the potential energy (PE) on the vertical axis and height (h) on the horizontal axis.

(b) **From the graph find :**

1- Values of a and b.

2- Mass of the body if $g = 10 \text{ m/s}^2$

3- Kinetic energy of the body at height 6 m. *(60 J , 5 m , 3 kg , 60 J)*

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18 A body of mass (m) falls freely from a height of 18 m from the surface of the ground. The following table demonstrates the relation between its kinetic energy and its speed during falling :

KE (J)	1	4	9	16	25	36
v (m)	1	2	3	4	5	6

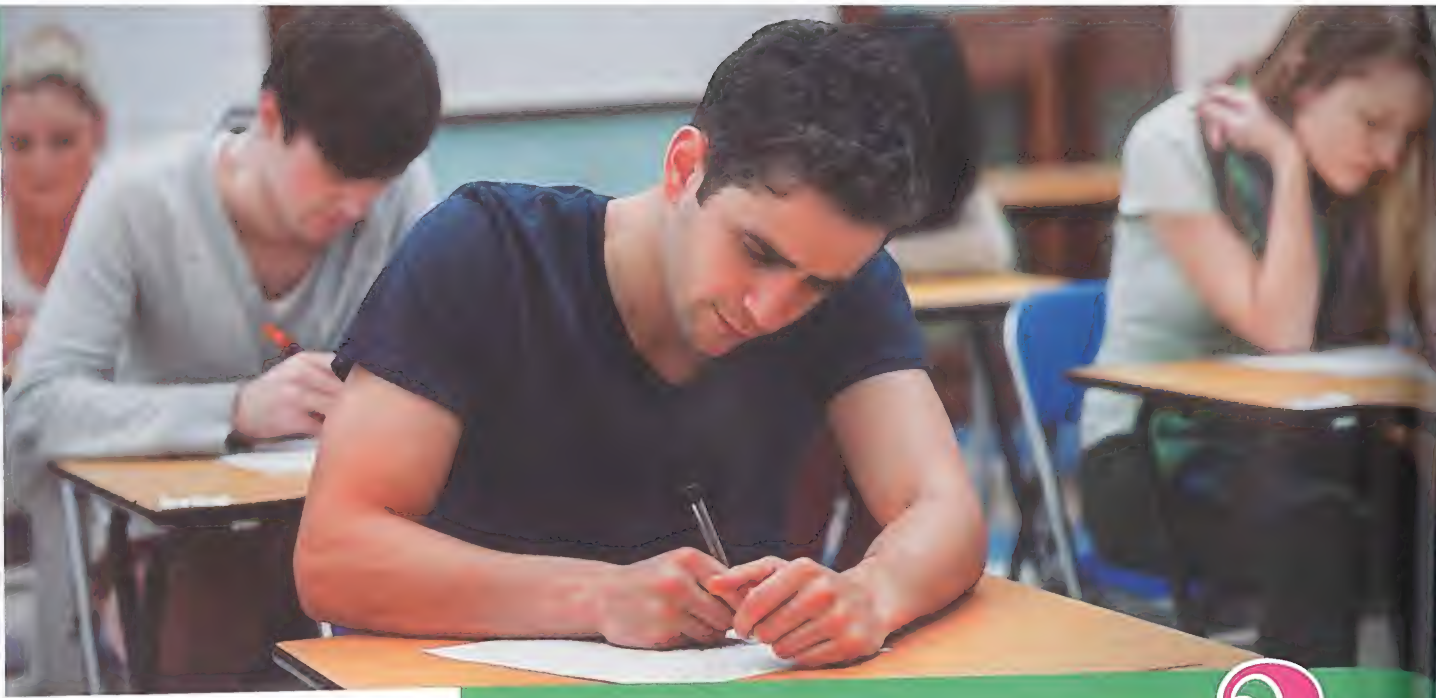
(a) **Draw the graphical** relation between the kinetic energy (KE) on the vertical axis and square of speed (v^2) on the horizontal axis.

(b) **From the graph find :**

1- Mass of the body. 2- Mechanical energy of the body.

3- Kinetic energy of the body at height 10 m.

(where : $g = 10 \text{ m/s}^2$) *(2 kg, 360 J, 160 J)*



MODEL EXAM ON

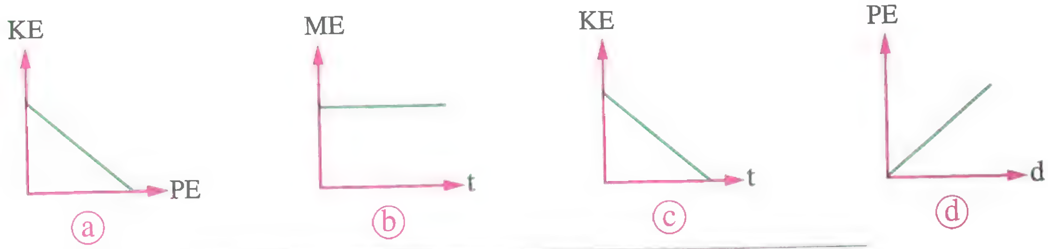
Chapter 2 Law of Conservation of Energy

First Choose the correct answer

1. An object is projected vertically upwards with a velocity of 20 m/s from the top of a building of height 15 m. So, the object's kinetic energy equals its potential energy at a height of .... from the ground. (where : $g = 10\ m/s^2$)

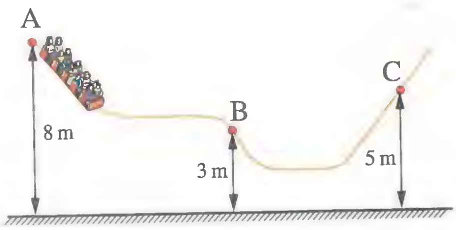
ⓐ 7.5 m ⓑ 15 m ⓒ 17.5 m ⓓ 35 m

2. Which of the following graphs does not express a body that is projected vertically upwards till it reaches the maximum height ? ....

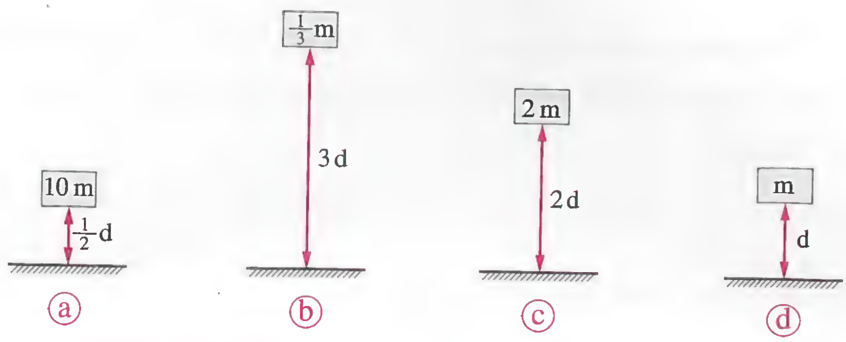


3. An amusement car starts its motion from rest at point A to move on a frictionless rails as shown in the following figure. Which of the following data is correct ? ....
(where : $g = 10\ m/s^2$)

	Velocity at B	Velocity at C
ⓐ	10	7.75
ⓑ	100	60
ⓒ	50	30
ⓓ	150	40



4 Which object in the following figures has the highest energy ? ....
(where : m is measured in kg and d is measured in meters)



5 A roller coaster car moves from the first hill that is at a height of 40 m with a speed of 2 m/s till it reaches the second hill that is at height of 15 m, with neglecting the friction and air resistance the speed of the car at the second hill will be .... ($g = 9.8\ m/s^2$)

(a) 11.55 m/s (b) 12.25 m/s (c) 18.22 m/s (d) 22.23 m/s

6 For an object that spent time (t) to fall freely from height (h) to the ground, which of the following is incorrect ? ....

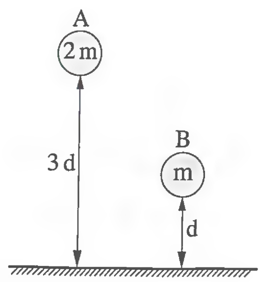
(a) Potential energy at height (h) = The mechanical energy

(b) Potential energy at height (h) = Kinetic energy when it reaches the ground

(c) Potential energy at $\frac{1}{2}$ (h) = Kinetic energy at $\frac{1}{2}$ (h)

(d) Potential energy after $\frac{1}{2}$ (t) = Kinetic energy after $\frac{1}{2}$ (t)

7 The opposite figure shows two bodies A , B that fall towards the ground at the same instant. The ratio between the kinetic energy of body A and that of body B at the instant of hitting the ground equals ....



(a) $\frac{1}{3}$ (b) $\frac{3}{1}$

(c) $\frac{1}{6}$ (d) $\frac{6}{1}$

8 A car of mass 1200 kg has a kinetic energy of 8.82×10^4 J. If its engine stops at the beginning of a bridge, so the maximum height that can be reached by the car (neglecting the lost energy due to the friction forces between the tyres and the bridge) is ....
(where : $g = 9.8\ m/s^2$)

(a) 7.5 m (b) 9.6 m (c) 12.4 m (d) 12.6 m

9. When an object is projected upwards, its mechanical energy ....

ⓐ increases ⓑ remains constant ⓒ decreases ⓓ equals the work

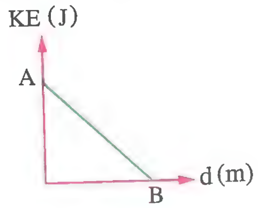
10. A 50 kg box slides down a frictionless inclined surface from a vertical height of 10 m. If the box starts from rest, what is the box's velocity at the bottom of the hill ? ....

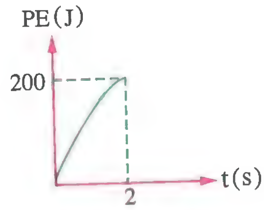
(where : $g = 10\ m/s^2$)

ⓐ 5 m/s ⓑ 10 m/s ⓒ 14 m/s ⓓ 24 m/s

Second Answer the following questions

11. The following graphs show the change in the potential and kinetic energies of an object that is projected upwards to the maximum height.





(a) **What** are the values of A and B ?

(b) **What** is the mass of the object ?

....

....

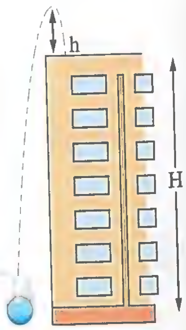
....

....

....

....

12. Sameh projected a ball of mass 0.5 kg upwards from the top of a building to fall down to the ground as in the opposite figure. If the mechanical energy of the ball at the top of the building is 100 J, **what** is its velocity at the instant of touching the ground ?



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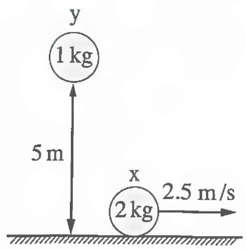
13 The opposite figure represents body (x) that moves horizontally and body (y) that falls freely from a height of 5 m, **calculate** the ratio of $\frac{(KE)_x}{(PE)_y}$ (where : $g = 10\ m/s^2$)



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14 If a body of mass 19 kg falls freely from a height of 60 m, **calculate** its kinetic energy at the midpoint of the falling distance. (where : $g = 10\ m/s^2$)

....

....

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....

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15 The potential energy of a body at height (h) from the ground is 200 J. If the body falls freely neglecting the friction forces, **calculate** the height (in terms of h) at which its kinetic energy will be 50 J.

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....

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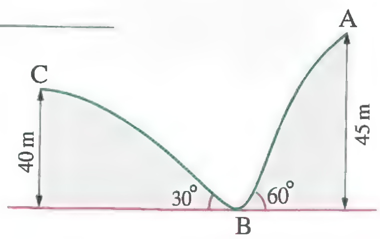
16 A ball slides from point A till it reaches point C as in the opposite figure. If the friction forces are neglected, **find** the velocity of the ball at point C.
(where : $g = 10\ m/s^2$)



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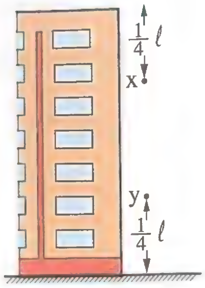
17 In the opposite figure there is a body that falls freely from the top of a building of height ℓ. **Find** the ratio between the kinetic energy at point x and the kinetic energy at point y.



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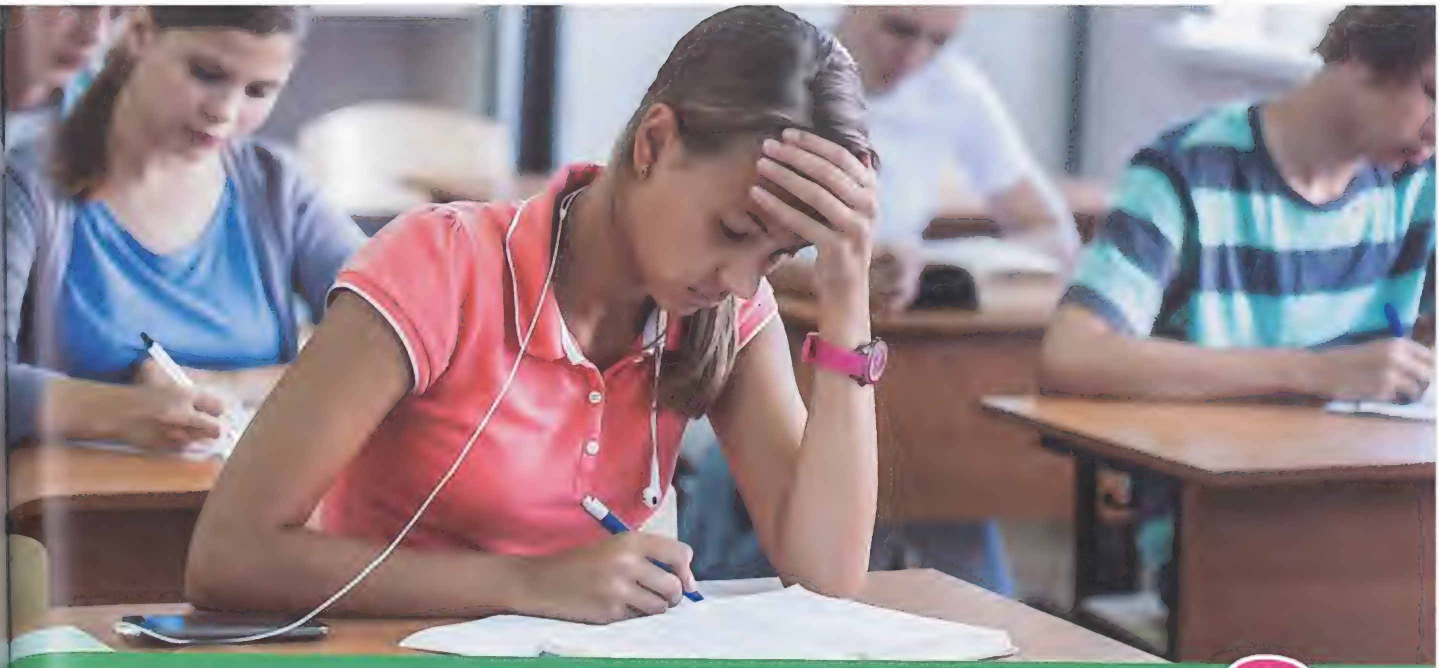
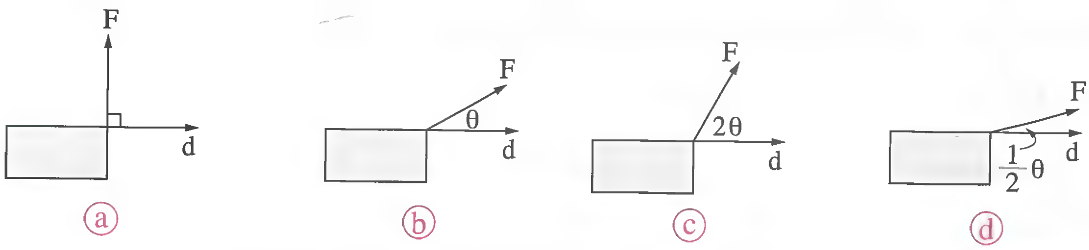


Accumulative Exam On Units 2, 3 & 4

First Choose the correct answer

1 The following figures represent four cases of a body that moves under the effect of a resultant force (F) in the direction shown in the figures, in which of the following cases the work done on the body is the largest ? ....



2 A car moves in a circular path of radius 10 m. If the tangential velocity of the car is 30 m/s, what is the car's acceleration ? ....

ⓐ 3 m/s^2 towards the center
ⓑ 3 m/s^2 away from the center
ⓒ 90 m/s^2 towards the center
ⓓ 270 m/s^2 towards the center

3 Which of the following variables will affect the orbital velocity of a satellite that orbits the Earth ? ....

ⓐ The mass of the satellite
ⓑ The height of the satellite above the Earth's surface
ⓒ The mass of the Earth
ⓓ Both ⓑ and ⓒ are correct

4. Two satellites orbit the Earth at the same speed in two identical orbits. Satellite A is twice the mass of satellite B. How can the centripetal acceleration of satellite A be compared with that of satellite B ? ....

(a) Four times as much
(b) Twice as much
(c) The same
(d) One-half as much

5. If a ball falls freely from the top of a tower, so the ratio between the work done on the ball due to the gravity in the 1st second and the work done on it in the 2nd second from starting its motion equals ....

(a) $\frac{1}{2}$
(b) $\frac{1}{3}$
(c) $\frac{1}{4}$
(d) $\frac{1}{5}$

6. An archer pulls bowstring back a distance of 20 cm with an average force of 75 N. The arrow has a mass of 20 gm. When he releases the string, the velocity of the arrow when it leaves the bow will be ....

(a) 1.2 m/s
(b) 22 m/s
(c) 32 m/s
(d) 39 m/s

7. An object of mass 0.5 kg at rest, started to fall from a height of 180 cm from the surface of the Earth. Its momentum when it reaches the Earth's surface is ....

(a) 3 kg.m/s
(b) 5 kg.m/s
(c) 6 kg.m/s
(d) 9 kg.m/s

8. An aircraft moves in a circular path of radius 1 km with a steady speed of 900 km/h. The ratio of its centripetal acceleration to the acceleration due to gravity is ....

(a) 9.2
(b) 6.25
(c) 5
(d) 8.25

9. A 70 kg astronaut floats at a distance of 10 m from a 50000 kg spacecraft. What is the attraction force between the astronaut and the spacecraft ? ....

(a) 2.4×10^{-6} N
(b) 2.4×10^{-5} N
(c) Zero, there is no gravity in space
(d) 2.4×10^{6} N

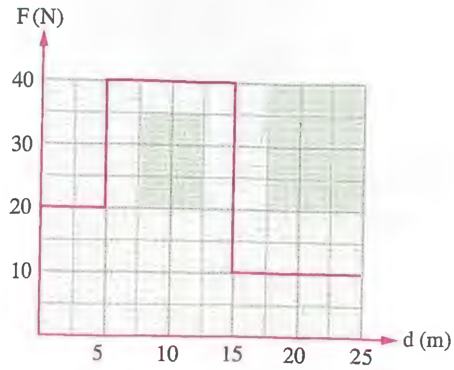
10. Two bodies x and y have the same mass, if $(KE)_x = 4\ (KE)_y$, then the momentum of x equals ....

(a) p_y
(b) $2\ p_y$
(c) $4\ p_y$
(d) $8\ p_y$

Second Answer the following questions

11 The opposite figure represents the relation between the force by which a worker pushes a box on a rough surface and the horizontal displacement moved by him.

Calculate the work done by the worker to push the box.



12 A car of mass 100 kg started motion from rest with a uniform acceleration where its momentum after 2 s was 4×10^3 kg.m/s. **Calculate** its momentum after 4 s from starting motion.

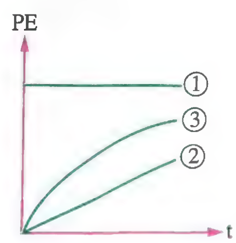
13 A block of mass 30 kg is located on the top of a horizontal frictionless table. This block is connected by a rope to another block of mass 10 kg. The rope is looped through a pulley on the table's edge so that the less massive block is hanging over the edge.

What is the magnitude of the acceleration of the larger block across the table ?

14 The opposite graph represents the relation between the potential energies of three bodies and the time, **which one of them represents :**

(a) A body that is projected vertically upwards.

(b) A body that is placed at a certain height.



15. You swing a 100 g object attached to a 2 m string in a circular path above your head. If the speed of the object is 12 m/s, **what** is the centripetal force acting on it ?

....

....

16. A 3 kg mass is located 10 cm away from a 6 kg mass. **What** is the resultant gravitational force acting on a 2 kg mass located at the midpoint of the line joining the first two masses ?

....

....

....

....

17. A crane pulls a car with a force of 3000 N to accelerate it at 3 m/s^2. **Find** the mass and the weight of the car. ($g = 9.8\ m/s^2$)

....

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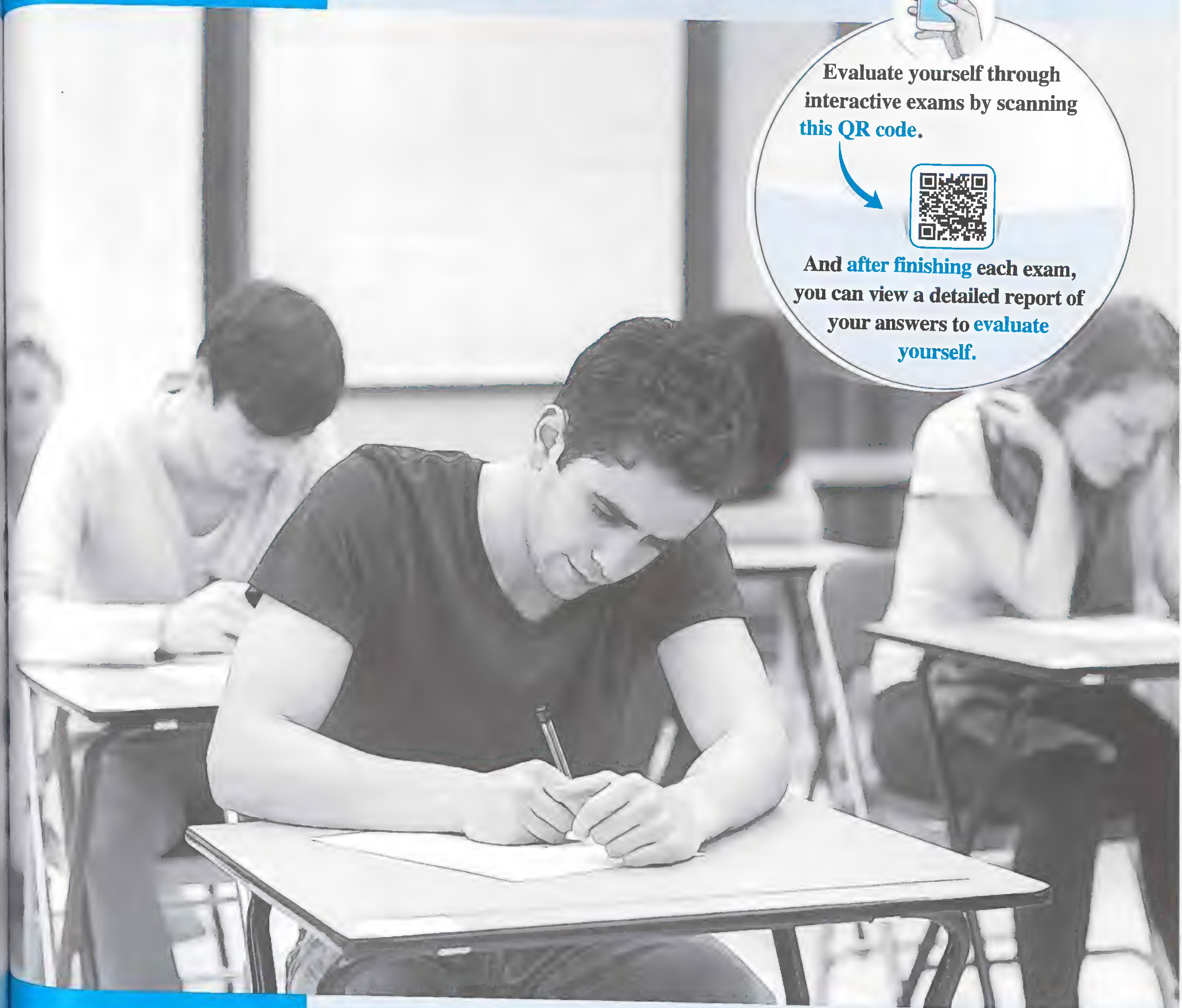
10 MODEL EXAMS



Evaluate yourself through interactive exams by scanning this QR code.

And after finishing each exam, you can view a detailed report of your answers to evaluate yourself.

Model Exam 1

First Choose the correct answer

1. A car of mass 1200 kg is moving with a velocity of 20 m/s. If the driver used the brakes and the speed of the car decreased to 8 m/s within 6 s , then the average force acting on the car during this period is ....

   (a) 2400 N in the same direction of motion
   (b) 2400 N in the opposite direction of motion
   (c) 1200 N in the same direction of motion
   (d) 1200 N in the opposite direction of motion

2. When an object moves in a uniform circular path, then ....

	The value of the linear velocity	The direction of the linear velocity
(a)	variable	constant
(b)	variable	variable
(c)	constant	variable
(d)	constant	constant

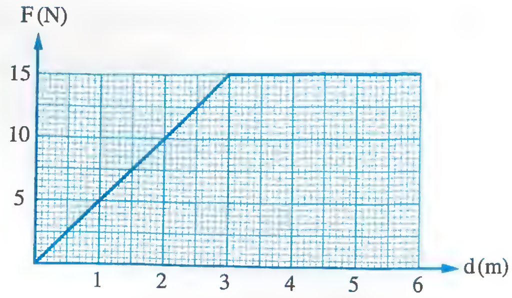
3. A child of mass 40 kg moves horizontally on a skating surface, then the work done by his weight when he moves a distance of 20 m is ....

   (a) zero (b) 800 J
   (c) 4000 J (d) 8000 J

4. An object is at height (h) from the ground and its potential energy is 200 J. If it falls to half this height , then the change in its kinetic energy equals ....

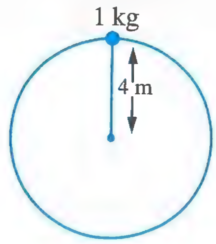
   (a) 50 J (b) 100 J
   (c) 150 J (d) 200 J

5 The opposite graph represents the relation between the net force (F) acting on a body moving in a certain direction and the displacement (d) covered by the body in the direction of motion, so the work done by this force on the body is ....



ⓐ 12.5 J　　ⓑ 37.5 J
ⓒ 45 J　　ⓓ 67.5 J

6 The opposite figure illustrates an object that rotates in a circular path under the effect of a centripetal force 100 N, so the periodic time of the object's motion is ....

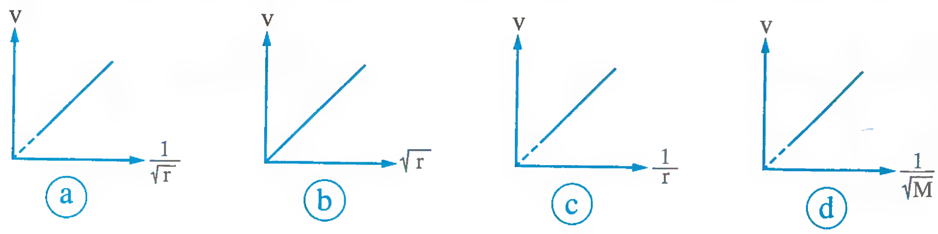


ⓐ 0.63 s　　ⓑ 1.26 s
ⓒ 3.14 s　　ⓓ 6.28 s

7 If the ratio between the mass of body A to that of body B is 2 : 1 and the ratio between the speed of body A to that of body B is 1 : 2 , then the ratio between the kinetic energy of body A to that of body B is ....

ⓐ 4 : 1　　ⓑ 2 : 1　　ⓒ 1 : 2　　ⓓ 1 : 4

8 Which of the following graphs represents the orbital velocity (v) of a satellite that orbits a planet ? ....
(where : (r) is the radius of the satellite's orbit, (M) is the mass of the planet.

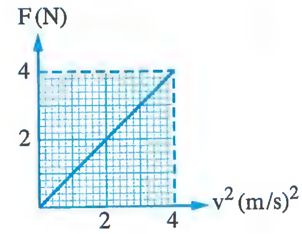


9 If the periodic time for the rotation of the Earth around the Sun is 365.25 days and the distance between the center of the Sun and that of the Earth is 1.496×10^{11} m , then the centripetal acceleration of the Earth towards the Sun is ....

ⓐ 5.94×10^{-3} m/s^2　　ⓑ 2.65×10^{-2} m/s^2
ⓒ 8.2×10^{-2} m/s^2　　ⓓ 4.63×10^{-3} m/s^2

10 The opposite graph illustrates the relation between the centripetal force (F) acting on a body of mass 2 kg that moves in a uniform horizontal circular motion and the square of the linear velocity (v^2) of the body.

So, the radius of the uniform circular path of the body equals ....



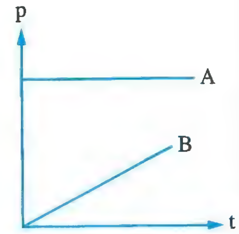
(a) 0.2 m (b) 0.5 m (c) 2 m (d) 4 m

Second Answer the following questions

11 The opposite graph represents the relation between the momentum of two bodies A , B and the time.

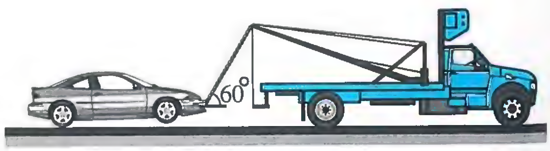
Illustrate which of the two bodies is affected by a resultant force?

Giving reasons.



12 A crane truck is pulling another car on a horizontal road for a distance of 1 km using a cable as in the opposite figure, thus it exerts a work of 10^5 J due to the tension in the cable.

Calculate the tension in the cable.

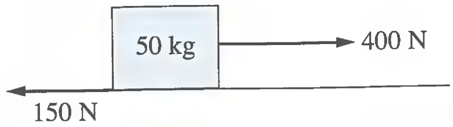


13 A body of mass 100 g moves in a uniform circular motion along the circumference of a circle of radius 50 cm, where it takes 90 s to make 45 complete revolutions. **Calculate** the centripetal acceleration of this body.

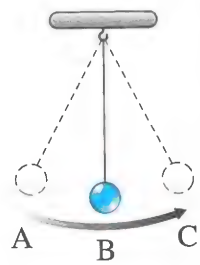
14 If the distance between the centers of the Sun and the Earth decreased to its half, **calculate** the number of days of the year on Earth assuming that the time of rotation of the Earth around its axis is the same.
(knowing that : the number of days of the year on Earth = 365.25 days)

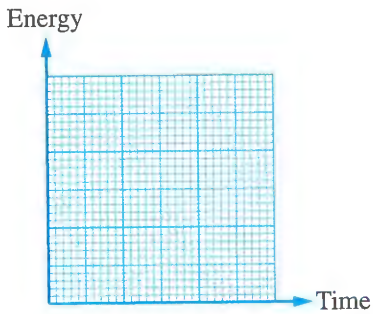
15 A man of weight 645 N is carrying a suitcase of mass 7.5 kg while climbing upstairs to a height of 8.2 m above the surface of the Earth. **Calculate** the work done by the man. ($g = 10\ m/s^2$)

16 In the next figure **calculate** the magnitude of the resultant force that acts on the mass and **also calculate** its acceleration :



17 The opposite figure illustrates a simple pendulum moving from position A to B to C.
Draw on the next graph the relation between each of the potential energy, the kinetic energy and the mechanical energy for the pendulum with time at the three positions.





Model Exam 2

First Choose the correct answer

1 At a height of .... from the surface of Earth, the acceleration due to gravity decreases 1 % of its value from that on the Earth's surface. (R_e = 6400 km)

ⓐ 60 km ⓑ 64 km ⓒ 30 km ⓓ 32 km

2 A truck of mass 4×10^3 kg started its motion from rest to a speed of 3 m/s under the effect of two forces, a forward one that is due to the engine and equals 3×10^4 N and the other is a backward one that is due to the friction and equals 28×10^3 N, so the displacement covered by the truck when it reaches a speed of 3 m/s is ....

ⓐ 9 m ⓑ 15 m ⓒ 20 m ⓓ 27 m

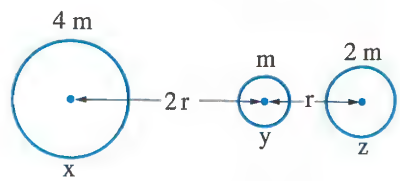
3 An object of mass 1 kg falls from a height of 180 m above the ground, so its momentum at the moment of the impact with the ground equals .... ($g = 10$ m/s^2)

ⓐ 60 kg.m/s ⓑ 120 kg.m/s
ⓒ 180 kg.m/s ⓓ 240 kg.m/s

4 The direction of the orbital velocity of a satellite that orbits the Earth makes an angle of .... with the direction of the gravitational force of the Earth.

ⓐ zero ⓑ 45° ⓒ 90° ⓓ 180°

5 The opposite figure shows three balls x , y and z which are placed at the same plane. So, the ratio of the gravitational force between the two balls x and y to the gravitational force between the two balls y and z equals ....



ⓐ $\frac{1}{2}$ ⓑ $\frac{8}{1}$
ⓒ $\frac{1}{4}$ ⓓ $\frac{1}{\sqrt{2}}$

6. A car is moving on a banked circular road (inclines on the horizontal at a certain angle), so the centripetal force acting on the car is due to ....

(a) the vertical component of the reaction force only
(b) the horizontal component of the friction force only
(c) the horizontal component of the reaction force only
(d) the sum of the two horizontal components of the reaction force and the friction force

7. A tennis ball and a bowling ball have fallen together from the same height in a room that is evacuated from air, so when they reach half the vertical height they will have the same ....

(a) speed
(b) potential energy
(c) kinetic energy
(d) mechanical energy

8. If the Moon rotates around the Earth once every 27.3 days, then its height from the Earth's surface equals ....

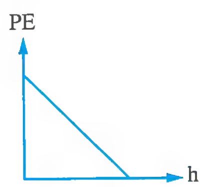
(where : $R_e = 6400$ km , $G = 6.67 \times 10^{-11}$ N.m^2/kg^2, $M_e = 6 \times 10^{24}$ kg)

(a) 3.54×10^7 m
(b) 3.96×10^7 m
(c) 3.24×10^8 m
(d) 3.77×10^8 m

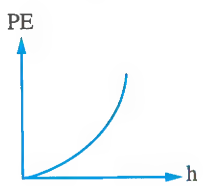
9. Two objects are moving on a frictionless horizontal surface, if $m_2 = 3\ m_1$ and $v_1 = 2\ v_2$, then the ratio between the kinetic energy of the first body and the kinetic energy of the second body is ....

(a) 3 : 2
(b) 2 : 3
(c) 3 : 4
(d) 4 : 3

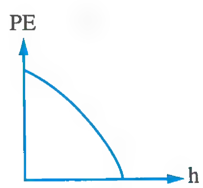
10. If an object is projected vertically upwards from the surface of the Earth, so the graph that represents the relation between the potential energy of the object and its height from the surface of the Earth is ....



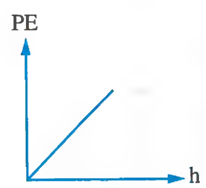
(a)



(b)



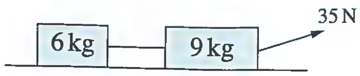
(c)



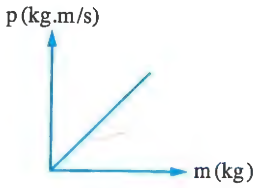
(d)

Second Answer the following questions

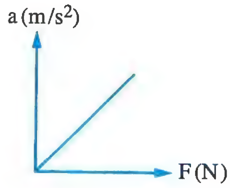
11 A force of 35 N acts on two cubes connected together through a rope to move them a distance of 2.7 m on a frictionless horizontal surface. If the change in their kinetic energies is 77 J, **calculate** the angle between the force's direction and the displacement's direction.



12 Write the mathematical relation and the equivalent for the slope of each of the following :



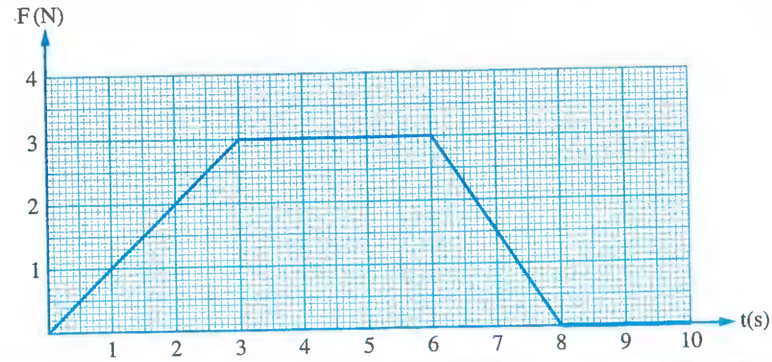
(a)



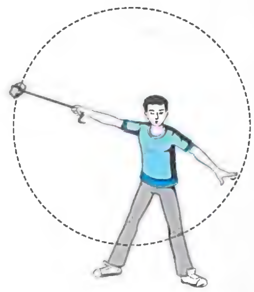
(b)

13 An object of mass (m) rotates in a uniform circular path of radius (r) to complete a cycle in time (T). If its periodic time is doubled, **prove that** the centripetal force acting on it decreases to its quarter.

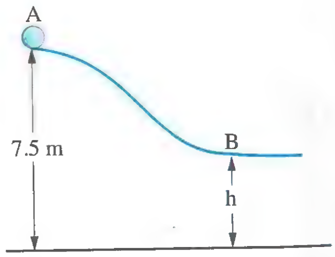
14 The following graph illustrates the net force (F) acting on a body of mass 1 kg within 10 s. **What** is the period in which the speed of the body is constant ?



15 **What** is the direction of the force that acts on a stone fixed at the end of a thread when it rotates in a circular path ? **And what** is the direction of the motion of the stone if the thread is cut ?



16 In the opposite figure a ball of mass (m) slides from rest at position A on a frictionless surface. If the speed of the ball at position B is 5 m/s. **Calculate** the height of position B from the Earth's surface. ($g = 10\ m/s^2$)



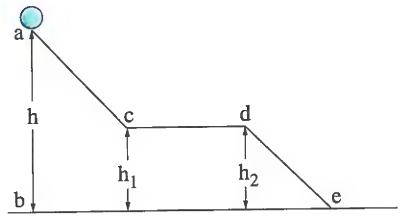
17 A car is moving in a curved road of radius 10 m. If the friction force between the tyres and the road is (numerically) equal to half the car's weight, **calculate** the speed of the car. ($g = 9.8\ m/s^2$)

Model Exam 3

First Choose the correct answer

1 In the opposite figure :

A ball is placed at the top of an inclined surface, it can reach the ground by falling vertically from a to b or by sliding on the inclined surface from a to e passing by points c and d. If we neglect air resistance and friction, then ....



(a) the kinetic energy at points c and d is the same

(b) the kinetic energy at points b and e is the same

(c) the mechanical energy at points b and d is the same

(d) all the previous

2 A body moves in a circular path of radius (r) with speed (v) under the effect of a centripetal force (F), if its speed increases to $\sqrt{2}$ v and moves in the same circular path , then the centripetal force affecting it will be ....

(a) 2 F (b) $\sqrt{2}$ F (c) $\frac{F}{\sqrt{2}}$ (d) $\frac{F}{2}$

3 A body moves with velocity 2 m/s , if a force of 8 N acts on it for 5 s in its direction of motion , then the change in the momentum of the body during this time is ....

(a) 8 kg.m/s (b) 24 kg.m/s (c) 40 kg.m/s (d) 48 kg.m/s

4 The centripetal force acting on a car that moves in a circular path is intiated from ....

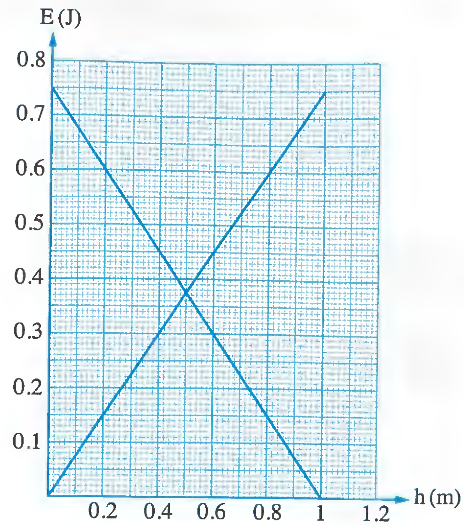
(a) the sum of the horizontal component of friction force and the vertical component of reaction force

(b) the sum of the horizontal components of friction force and reaction force

(c) the reaction force only

(d) the friction force only

5 The opposite graph represents the change of both kinetic energy and potential energy of a body during its fall towards the ground , so the mechanical energy of the body equals ....



ⓐ 0.35 J

ⓑ 0.6 J

ⓒ 0.75 J

ⓓ 0.8 J

6 A satellite orbits a planet at a height of 10^6 m from the center of the planet , if the acceleration due to gravity at its orbit is 4 m/s^2 , then its orbital velocity is ....

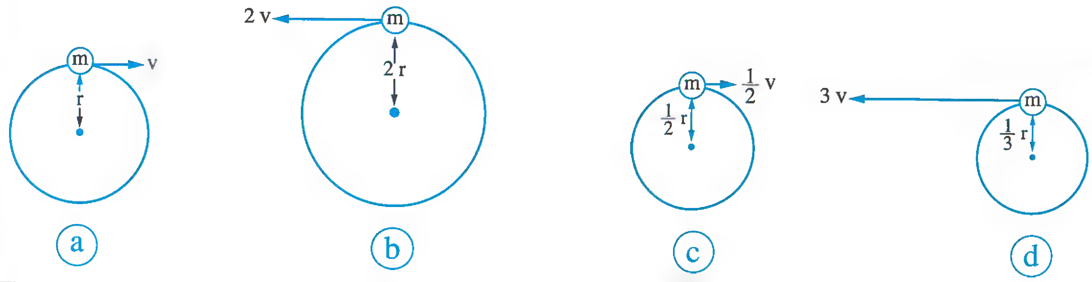
ⓐ 2×10^6 m/s ⓑ 4×10^6 m/s ⓒ 2×10^3 m/s ⓓ 10^3 m/s

7 If the kinetic energy of a car decreased to its quarter , then its momentum ....

ⓐ decreases to its quarter ⓑ decreases to its half

ⓒ increases to its quadruple ⓓ remains constant

8 The following figures represent the motion of four bodies that move in uniform circular paths, which one of these bodies is affected by the largest centripetal force ? ....



9 The distance between two bodies is r , if the mass of one body is doubled , so the value of the change in the distance between them has to be .... to make the attraction force between them decreases to its half.

ⓐ $\frac{r}{4}$ ⓑ $\frac{r}{2}$ ⓒ r ⓓ 2 r

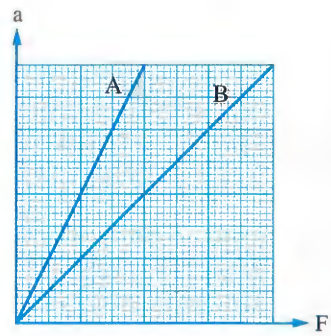
10 A body of weight 60 N has a kinetic energy of 27 J , so the momentum of the body is .... ($g = 10\ m/s^2$)

ⓐ 21 kg.m/s ⓑ 18 kg.m/s ⓒ 15 kg.m/s ⓓ 9 kg.m/s

Second Answer the following questions

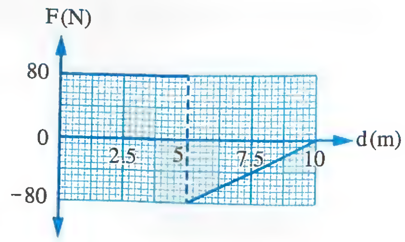
11 A boy holds a string with an attached stone at its end and moves it in a horizontal plane as the direction of the arrow shown in the opposite figure. If the boy released the string suddenly when the stone is at x , **show with drawing** the direction of motion of the stone at the instant of releasing.

12 The opposite graph represents the change of the acceleration with the change of the magnitude of the resultant force that acts on two different bodies A and B. **Calculate** the ratio between the mass of body A and the mass of body B.

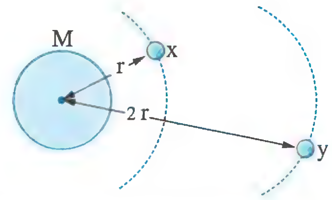


13 Two identical balls were projected from the top of a building , one of them was projected vertically upwards and the other was projected vertically downwards with the same initial velocity , **compare between** their kinetic energies at the instant of colliding with the ground.

14 The opposite graph represents the relation between the force acting on a body and the displacement moved by this body due to the acting force.
Calculate the work done on the body by this force.



15 The opposite figure represents two planets x and y that orbits star M. If the mass of planet x is 10^{24} kg and the attraction force of the star to the two planets is the same, **calculate** the mass of planet y.



16 **Calculate** the mass of the Earth , if you know that the acceleration due to gravity at its surface is 9.8 m/s^2 , universal gravitational constant is 6.67×10^{-11} $N.m^2/kg^2$ and the radius of Earth is 6.36×10^6 m.

17 A body of mass 35 kg is lifted to the top of a building by using a rope that can withstand a maximum tension of 490 N, **calculate** the maximum acceleration that can be reached by the body during lifting it.

($g = 10\ m/s^2$)

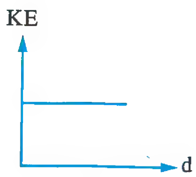
Model Exam 4

First Choose the correct answer

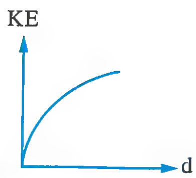
1 A satellite orbits a planet with a tangential velocity of 9 km/s , if the distance between the satellite and the center of the Earth is 5.43×10^6 m , then the periodic time of the satellite is ....

(a) $1.21\,\pi \times 10^6$ s
(b) $1.21\,\pi \times 10^3$ s
(c) $6\,\pi \times 10^6$ s
(d) $6\,\pi \times 10^3$ s

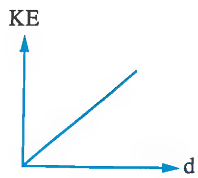
2 If a body starts motion from rest with uniform acceleration (a) , so the graphical representation that shows the relation between the covered displacement and the kinetic energy is ....



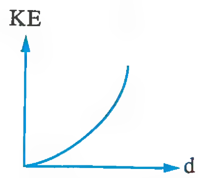
(a)



(b)



(c)



(d)

3 A person tried to push a box of mass 50 kg that is placed on a horizontal rough plane but he couldn't , so the resultant of the forces acting on the box is .... ($g = 10$ m/s^2)

(a) 0
(b) 50 N
(c) 500 N
(d) unknown value

4 Two identical tangent balls each of mass (m) and radius (r) attract each other by a mutual gravitational force that equals ....

(a) $\frac{Gm^2}{r^2}$
(b) $\frac{Gm^2}{4\,r^2}$
(c) $\frac{2\,Gm}{4\,r^2}$
(d) $\frac{Gm^2}{2\,r^2}$

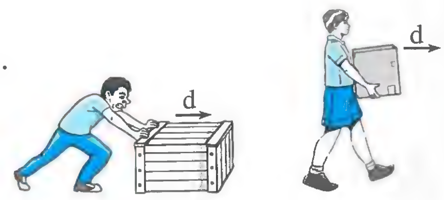
5 By increasing the distance between the satellite and the center of the Earth , the ....

	Periodic time	Orbital velocity
a	decreases	decreases
b	increases	increases
c	decreases	increases
d	increases	decreases

6 A pilot drives a jet with a velocity of 60 m/s in a uniform circular path of radius 190 m. If the centripetal force required to keep the jet in its circular path is 2×10^4 N, so the mass of the jet equals ....

a 950.28 kg
b 1055.56 kg
c 1120.42 kg
d 1450.36 kg

7 In the opposite figure :



(A) (B)

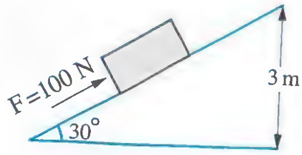
a The hands of the two men A and B are doing work.
b The hands of man A are doing work , while the hands of man B aren't doing work.
c The hands of man B are doing work , while the hands of man A aren't doing work.
d The hands of the two men A and B aren't doing work.

8 A satellite of mass 10^3 kg orbits a planet of mass 10^{24} kg in an orbit apart from the center of the planet by 6.67×10^5 m , so the orbital velocity of the satellite is ....
(knowing that : $G = 6.67 \times 10^{-11}$ N.m^2/kg^2)

a 10^4 m/s
b 10^5 m/s
c 10^3 m/s
d 6.67×10^3 m/s

9 In the opposite figure :

The work done by the force F to push the box upwards from the ground to the top of the inclined plane is ....



(a) 300 J (b) 450 J (c) 600 J (d) 750 J

10 The attraction force between two bodies is 0.04 N , if the distance between them is doubled , so the attraction force between them becomes ....

(a) 0.16 N (b) 0.08 N (c) 0.02 N (d) 0.01 N

Second Answer the following questions

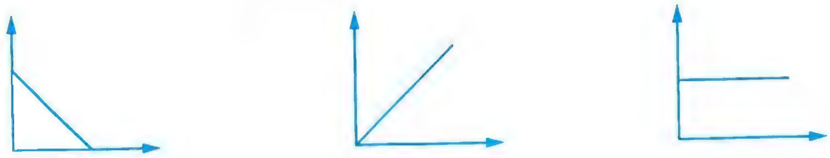
11 An object moves in a uniform circular path with a tangential velocity of 10 m/s to cover a distance of $10\sqrt{2}$ m during $\frac{1}{4}$ revolution. **Calculate** the periodic time of this object.

12 **Calculate** the ratio between the acceleration due to gravity on the surface of the Moon to that on the surface of the Earth , if you know that the mass of the Earth is 5.976×10^{24} kg and its radius is 6.4×10^{6} m and the mass of the Moon is 7.35×10^{22} kg and its radius is 1.74×10^{6} m.

13 A body is projected vertically upwards and you have three graphical representations to show the relation between some physical quantities of this body , **which of them represents the relation between :**

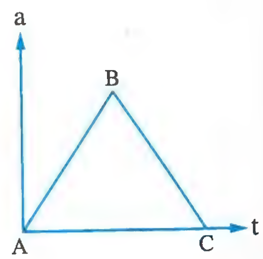
(a) The kinetic energy and the height of the body from the ground.

(b) The mechanical energy and the height of the body from the ground.



(1) (2) (3)

14 The opposite graph represents the change in the acceleration of a body which starts its motion from rest with time , **at which point the momentum of the body is :**



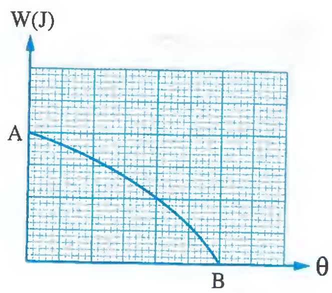
(a) zero.

(b) maximum.

15 A resultant force (F) acts on a body of mass (m) to accelerate it by acceleration (a). If a resultant force (4F) acts on another body of mass (2 m), **calculate** the acceleration acquired by the second body in terms of a.

16 The following figures show three identical cars of the same mass (m) , **compare between** the maximum acceleration reached by the three cars after passing the traffic lights , neglecting the friction force.

17 The opposite graph represents the relation between the work done and the angle between the force line of action and the direction of motion , if the force that causes motion is 100 N and the displacement is 5 m , **find :**



(a) The work done at point A.

(b) The angle at point B.

Model Exam 5

First Choose the correct answer

1 A satellite is orbiting the Earth with a speed of 8.4×10^3 m/s. If the satellite takes 1.6 h to complete one cycle , so the length of the circular path of the satellite equals ....

(a) 3.62×10^4 km (b) 3.95×10^4 km
(c) 4.52×10^4 km (d) 4.84×10^4 km

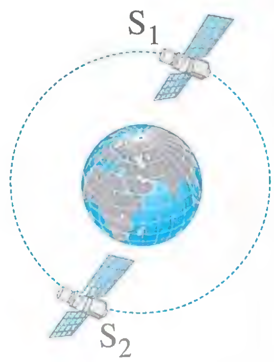
2 A car of mass 1250 kg travels with a velocity of 29.2 m/s , so the work done by the brakes to stop the car approximately equals ....

(a) 426 kJ (b) 533 kJ (c) – 426 kJ (d) – 533 kJ

3 A girl pulls a small cart of mass 0.5 kg on a horizontal frictionless road with a force of 25 N , so the force of gravity that pulls the cart is .... ($g = 10$ m/s^2)

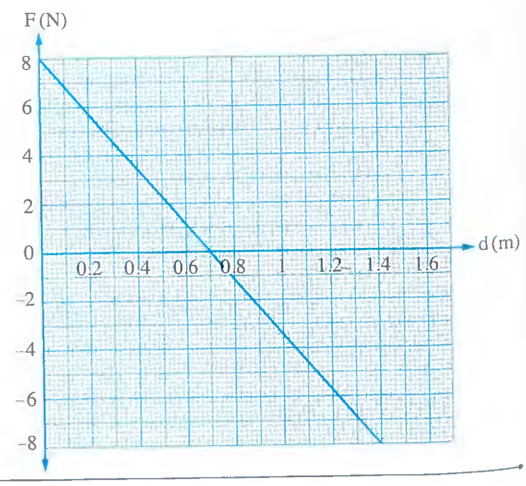
(a) 0.5 N (b) 5 N (c) 20 N (d) 25 N

4 In the opposite figure two satellites S_1 , S_2 of masses m , 2 m respectively orbit the Earth at the same height , so the ratio between the periodic time of S_1 and the periodic time of S_2 is ....



(a) $\frac{2}{1}$ (b) $\frac{\sqrt{2}}{1}$
(c) $\frac{1}{2}$ (d) $\frac{1}{1}$

5 The opposite graph represents the relation between the force that acts on a body and the displacement of that body in the direction of that force , so the work done on the body by the force equals ....



(a) 0
(b) 5.6 J
(c) 6.5 J
(d) 8.6 J

6 A roller coaster car moves from the first hill that is at a height of 40 m with a speed of 2 m/s till it reaches the second hill that is at height of 15 m, with neglecting the friction and air resistance the speed of the car at the second hill will be .... ($g = 9.8\ m/s^2$)

ⓐ 11.55 m/s ⓑ 12.25 m/s ⓒ 18.22 m/s ⓓ 22.23 m/s

7 A stone is attached to a string and rotates in a horizontal plane. If the string is cut , the stone ....

ⓐ continues its motion around the center with the same speed

ⓑ continues its motion around the center with less speed

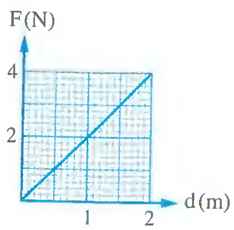
ⓒ falls directly to the ground

ⓓ moves in a tangent direction to the circular path

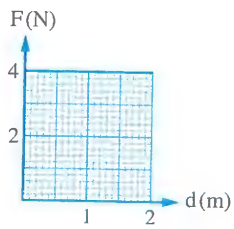
8 A satellite orbits the Earth in a uniform circular path with an orbital velocity $\sqrt{\frac{2\ GM}{3\ R}}$ where M is the Earth's mass and R is its radius. So the height of the satellite from the surface of the Earth equals ....

ⓐ R ⓑ $\frac{2\ R}{3}$ ⓒ $\frac{3\ R}{2}$ ⓓ $\frac{R}{2}$

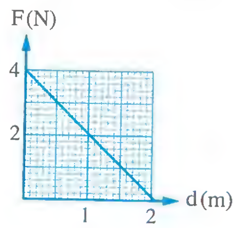
9 The following graphs shows the relation between the force (F) that acts on different moving objects and the displacements (d) that moved by these objects in the direction of the force. Which of these objects has the biggest work done ? ....



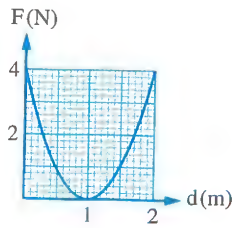
ⓐ



ⓑ



ⓒ



ⓓ

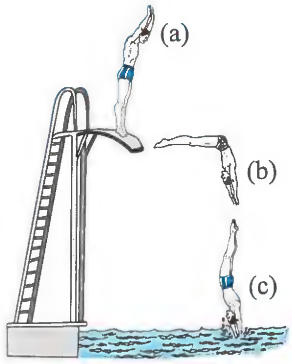
10 A ball of mass 2 kg falls from a height of 20 m on a hard plane surface and collides with it. If the ball's energy decreases by 76 J due to the collision, so it will rebound upwards with velocity of .... ($g = 10\ m/s^2$)

ⓐ 12 m/s ⓑ 14 m/s ⓒ 16 m/s ⓓ 18 m/s

Second Answer the following questions

11 In the opposite figure :

At which position the kinetic energy of the man has the greatest value ? **And why ?**



12 A motorbike driver climbs up a hill that has a half-circled shape of radius 50 m. **Calculate** the maximum speed that can be reached by the bike at the top of the hill where it still touching the hill. ($g = 10\ m/s^2$)

13 When you jump from a certain height on the ground you bend your knees at the instant of touching the ground by your feet. **Explain this.**

14 A boy held the end of a string and attached a ball of mass 0.2 kg to the other end then he moved his hand to make the ball rotate in a circular path of radius 60 cm with a uniform speed of π m/s, **calculate** the tension force in the string.

15 A body of mass (m) moves in a circular path with a speed (v) counter clockwise due to a centripetal force F , **which of the following figures represents :**

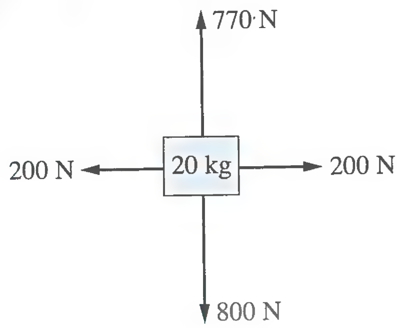
(a) The centripetal acceleration direction.

(b) The linear velocity direction.

(1) (2) (3) (4)

16 A skier of mass 52 kg moves by a velocity of 2.5 m/s, **calculate** the work done by the friction with the ice to stop the man after a distance of 24 m.

17 **Calculate the net force and the acceleration in the following figure :**

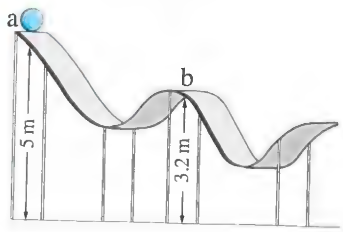


Model Exam 6

First Choose the correct answer

1 In the opposite figure :

A ball slides from rest at point (a) through a path of negligible friction, so the velocity of the ball at point (b) equals .... ($g = 10\ m/s^2$)



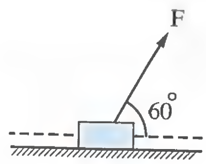
(a) 4 m/s
(b) 5 m/s
(c) 6 m/s
(d) 7.5 m/s

2 Two satellites A and B orbit a planet, if the radii of their orbits are 2×10^6 m and 10^6 m respectively and the periodic time of satellite B is 8×10^7 s, so the periodic time of satellite A equals ....

(a) 5×10^5 s (b) 4×10^6 s (c) 2.3×10^8 s (d) 4.5×10^8 s

3 In the opposite figure :

A wooden box is placed on a smooth horizontal plane, then a force F acts on it, if the work done to move the box by a displacement 20 m equals 1000 J, then the acting force F equals ....



(a) 2000 N (b) 1000 N (c) 200 N (d) 100 N

4 A satellite A orbits Earth and another satellite B orbits Mars, if their orbits' radii is the same and the mass of the Earth is 9 times that of the Mars, then the ratio between the linear velocity of satellite A to that of satellite B equals ....

(a) $\frac{1}{9}$ (b) $\frac{1}{3}$ (c) $\frac{3}{1}$ (d) $\frac{9}{1}$

5 The egg usually breaks when it falls on the ground, while it doesn't break when it falls on a pillow from the same height because in case of breaking ....

(a) the change in momentum is larger

(b) the change in momentum is smaller

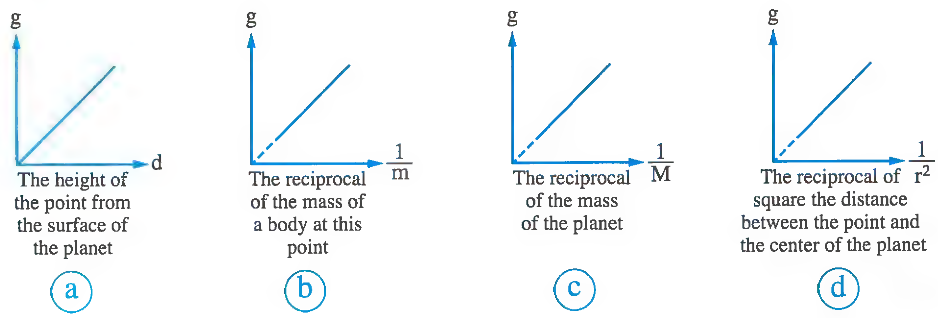
(c) the time of impact is larger

(d) the time of impact is smaller

6 A body of mass 2 kg fell from a height of 10 m on a muddy soil, then it moved 4 cm inside the soil, so the average force acting on the body due to the soil is .... ($g = 10\ m/s^2$)

(a) – 200 N (b) – 3000 N (c) – 5000 N (d) – 8000 N

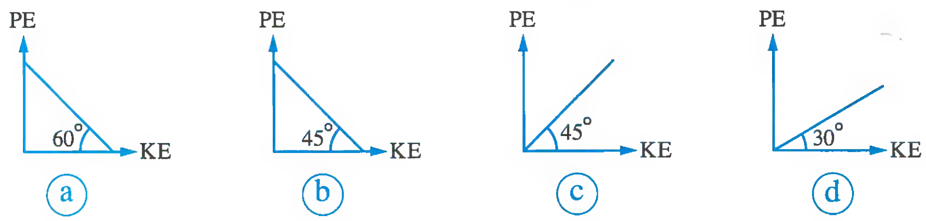
7 The best graphical representation for the gravitational field intensity of a planet at a point is ....



8 Two bodies of the same mass, if two different forces acted on them where the ratio between them is $\frac{3}{1}$, then the ratio between the accelerations of the two bodies respectively is ....

(a) $\frac{1}{3}$ (b) $\frac{3}{1}$ (c) $\frac{1}{9}$ (d) $\frac{9}{1}$

9 The best graphical representation for the change of KE and PE of a body falling freely in the Earth's gravitational field from a certain height is ....



10 The acceleration due to gravity on the surface of a planet of mass 7×10^{21} kg and radius 500 km equals .... (knowing that : $G = 6.67 \times 10^{-11}\ N.m^2/kg^2$)

(a) $21.21\ m/s^2$ (b) $12.08\ m/s^2$ (c) $8.22\ m/s^2$ (d) $1.87\ m/s^2$

Second Answer the following questions

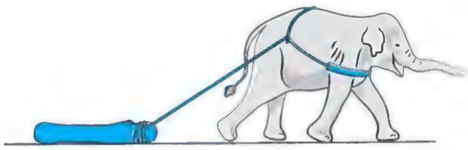
11 The gravitational force appears between cosmic bodies, but doesn't appear between people. **Explain.**

12 A car starts to move in a wet (slippery) curved road where its driver notices that the car skids away from the curved road, **explain this.**

13 A man attaches a ball of mass 0.25 kg on one of the ends of a rope then he rotates it in a horizontal plane from the other end with a linear velocity of 5 m/s. If the distance between the center of the ball and the center of rotation is 1 m and the maximum tension force that the rope can withstand is 12 N, **will** the rope cut ? **And why ?**

14 A satellite orbits a planet at a height of 10^6 m from the center of the planet, if the acceleration due to gravity at its orbit is 9 m/s^2, **calculate** its orbital velocity.

15 An elephant pulls a log of mass 1 ton on a horizontal surface with a velocity that changes uniformly from 1 m/s to 4 m/s during 2 s. If the friction forces between the log and the ground surface equal 400 N, **calculate** the horizontal component of the tension force in the rope.



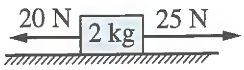
16 A ball of mass 3 kg moves on a horizontal plane with a velocity of 2 m/s, it collides with a wall and rebounds by half its velocity. **Calculate** the lost energy due to the collision.

17 A body of mass 8 kg penetrates a wooden surface with a velocity of 20 m/s, so its velocity decreases because of the friction till it completely stops after covering a distance of 40 m. **Calculate** the magnitude of the average friction force.

Model Exam 7

First Choose the correct answer

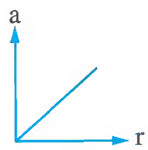
1 In the opposite figure :



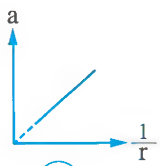
The object moves with a uniform acceleration of ....

(a) $2.5\ m/s^2$ (b) $7.5\ m/s^2$ (c) $10\ m/s^2$ (d) $12.5\ m/s^2$

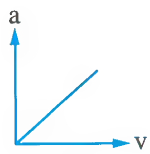
2 The graph that represents the centripetal acceleration of a body that moves in a circular path is ....



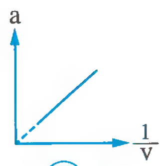
(a)



(b)



(c)

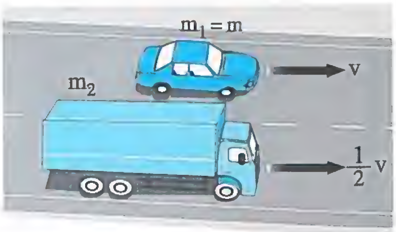


(d)

3 A small car of mass 700 kg was moving with a velocity of 18 m/s on a horizontal road. When the driver applied the brakes the car was affected by a constant force and its velocity became 25 m/s. So the work done by this force equals ....

(a) 2.75×10^5 J (b) 2.2×10^5 J (c) 1.05×10^5 J (d) 10^5 J

4 The opposite figure shows two vehicles of equal kinetic energy, so the magnitude of m_2 is ....



(a) m (b) 2 m

(c) 4 m (d) 8 m

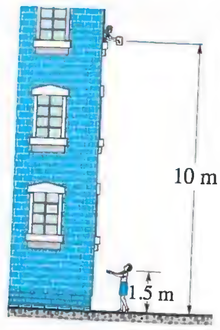
5 A satellite of mass 300 kg orbits the Earth. If its linear momentum is 1.77×10^6 kg.m/s , then the radius of its orbit equals ....

(knowing that : $G = 6.67 \times 10^{-11}\ N.m^2/kg^2$, $M_e = 5.98 \times 10^{24}$ kg)

(a) 5.73×10^3 km (b) 8.59×10^3 km

(c) 11.46×10^3 km (d) 17.18×10^3 km

6 A man drops a body of mass 0.2 kg from a height of 10 m above the ground, another man catches that body at a height of 1.5 m above the ground. So, ... ($g = 10\ m/s^2$)

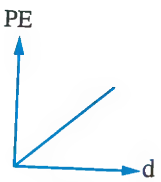


	The work done on the body (J)	The change in potential energy of the body (J)
a	20	20
b	20	17
c	17	20
d	17	17

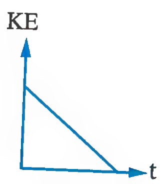
7 A satellite orbits Earth at a height that equals $\frac{1}{3}$ of the Earth's radius. If the acceleration due to gravity on the Earth's surface is $10\ m/s^2$, then the acceleration due to gravity at this height equals ....

a) $2.5\ m/s^2$ b) $5.6\ m/s^2$ c) $10\ m/s^2$ d) $30\ m/s^2$

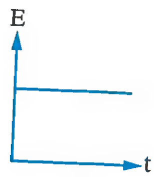
8 Which graph of the following graphical representations doesn't represent a body that is projected vertically upwards till it reaches its maximum height ? ....



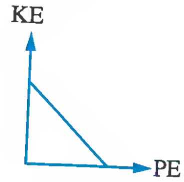
a



b



c



d

9 Two balls are hanged where the distance between their centers is 0.4 m, if their weights are 1.96×10^2 N and 9.8×10^2 N, so the gravitational attraction force between them approximately equals .... (where : $G = 6.67 \times 10^{-11}\ N.m^2/kg^2$, $g = 10\ m/s^2$)

a) 6×10^{-7} N b) 8×10^{-7} N c) 9×10^{-7} N d) 10^{-6} N

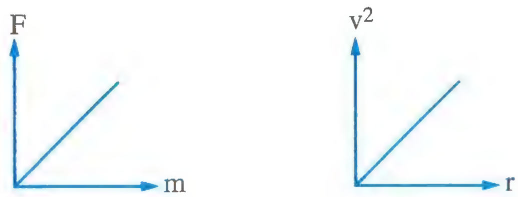
10 A body rotates in a circular orbit of radius $\frac{10}{\pi}$ m. If it completes one cycle in 0.5 s , its tangential velocity is ....

a) π m/s b) 40 m/s c) 100 m/s d) $100\ \pi$ m/s

Second Answer the following questions

11 When an object moves with a uniform velocity on a frictionless horizontal surface the work done on it by the resultant force equals zero. **Explain.**

12 **What is the mathematical equation and the slope of the line in each of the following graphs :**



(1) (2)

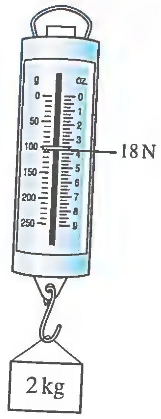
Where : (F) is the acting force on a body that moves in a straight line, (m) is the mass of the body, (v^2) is the square of the tangential velocity and (r) is the radius of the circular path.

13 Ahmed climbs a mountain across a short steep road (inclines on the horizontal at large angle). Mohamed climbs the same mountain across a long paved road (inclines on the horizontal at very small angle). **Compare between** the work done by gravity on each of them, **with explaining your answer.**

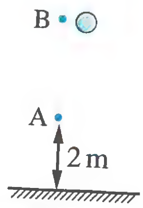
14 The following table shows the weights of the same object on four different planets :

The planet	The weight of the object (N)
Earth	100
Jupiter	250
Mercury	40
Venus	90

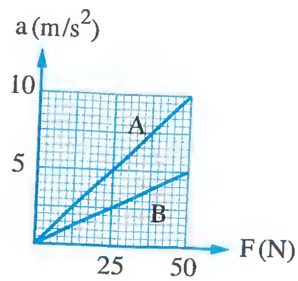
What is the planet where the weight of an object of mass 2 kg on it is as shown in the opposite figure ? ($g = 10\ m/s^2$)



15 In the opposite figure a body of 10 kg falls freely.
If its mechanical energy at point B is 800 J, **calculate** its kinetic energy at point A. ($g = 10\ m/s^2$)



16 The opposite graph shows the relations between the accelerations of two cars A , B and the forces that causes them, **calculate** the ratio between the mass of A and the mass of B.



17 Two moons are orbiting a planet. If the first moon takes 20 days to complete one cycle around the planet at a distance of 2×10^5 km from the planet's center while the other moon takes 160 days, **calculate** the distance between the second moon and the center of the planet.

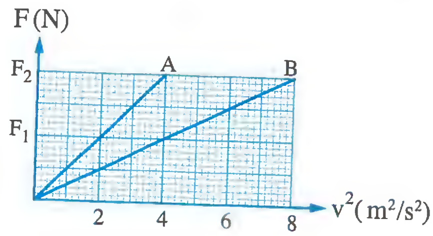
Model Exam 8

First Choose the correct answer

1 Airbags are used to protect the drivers because they reduce the force of impact as a result of ....

(a) increasing the time interval of the change in momentum
(b) increasing the momentum
(c) decreasing the time interval of the change in momentum
(d) decreasing the momentum

2 The opposite graph represents the relation between the centripetal force that acts on two bodies A , B that have the same mass and the square of the linear velocity by which each of them move in a uniform circular path. So, the ratio between the radii of the two orbits ($\frac{r_A}{r_B}$) is ....



(a) $\frac{1}{2}$ (b) $\frac{\sqrt{2}}{1}$ (c) $\frac{4}{1}$ (d) $\frac{1}{4}$

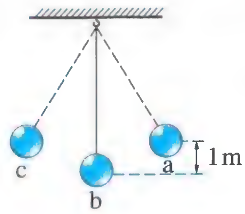
3 A body rotates in a circular path with a speed of 10 m/s. If the moved distance during a half cycle is 44 m, so the periodic time of its circular motion is ....

(a) 22 s (b) 8.8 s (c) 4.4 s (d) $\frac{22}{7}$ s

4 A work is done on a body so its kinetic energy is doubled. If the velocity of the body before exerting the work was v_1, so its velocity after its kinetic energy was doubled is ....

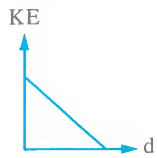
(a) $\sqrt{2}\ v_1$ (b) $2\ v_1$ (c) $\sqrt{3}\ v_1$ (d) $4\ v_1$

5 The opposite figure represents a pendulum ball of mass 15 g that starts its motion from point b and its velocity reaches zero at positions a and c , so .... ($g = 10\ m/s^2$)

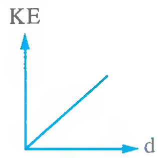


	The maximum value of the PE (J)	The maximum value of the KE (J)
(a)	0.3	0.3
(b)	0.15	0.3
(c)	0.3	0.15
(d)	0.15	0.15

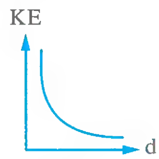
6 The graph that represents the relation between the kinetic energy of a body (KE) that falls freely and its distance (d) from the original position is ....



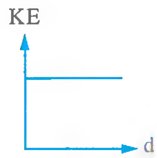
(a)



(b)



(c)



(d)

7 A satellite rotates in a circular path around the Earth at a distance above the Earth's surface twice the radius of the Earth, so the acceleration due to gravity at the position of the satellite is ....

(where : $g_{\text{at the surface of the Earth}} = 9.8\ m/s^2$)

(a) $1.09\ m/s^2$ (b) $3.27\ m/s^2$ (c) $4.9\ m/s^2$ (d) $2.45\ m/s^2$

8 A satellite orbits in a circular path of radius twice as the radius of Earth, so the time required by the satellite to complete one cycle around the Earth is ....

(where : $R_e = 6400$ km , $G = 6.67 \times 10^{-11}\ N.m^2/kg^2$, $M_e = 6 \times 10^{24}$ kg)

(a) 14.39×10^3 s (b) 15.1×10^3 s

(c) 15.96×10^3 s (d) 16.2×10^3 s

9 A body of mass 19 kg falls freely from a height of 60 m, so its kinetic energy at the middle of the falling distance equals .... ($g = 10\ m/s^2$)

(a) 2850 J (b) 5700 J (c) 8550 J (d) 11400 J

10 A body rotates in a uniform circular path of radius 25 cm due to the effect of a centripetal force that equals 4 times the body's mass numerically. So, the tangential velocity of the body after $\frac{1}{4}$ revolution is ....

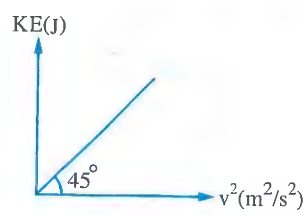
(a) 0.5 m/s (b) 1 m/s (c) 1.5 m/s (d) 2 m/s

Second Answer the following questions

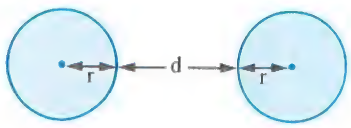
11 An egg breaks when it falls on the ground and doesn't when it falls on a pillow.
Give reasons.

12 **What** is the direction of the force that the seat belt of a car exerts on the driver when the car drifts ?

13 The opposite graph represents the relation between the kinetic energy of a body and the square of its velocity when representing it by the same scale of drawing, **calculate** the mass of the body.



14 The opposite figure shows two identical spheres, where the gravitational force between them equals $\frac{Gm^2}{16\ r^2}$, **calculate** the value of the distance d.



15 A body of mass 10 kg is projected vertically upwards where its velocity at a height of 5 m from the ground is 5 m/s. **Calculate** its velocity at a height of 2 m from the ground. ($g = 10\ m/s^2$)

16 A crane pulls a car horizontally by a force of 3000 N to move it with an acceleration of $3\ m/s^2$, **find** the mass and the weight of the car. ($g = 10\ m/s^2$)

17 A planet of mass M has two moons of masses m_1 and m_2 that rotate in two orbits of radii R_1 and R_2 respectively. If the attraction between the two moons is neglected and $m_1 = 2\ m_2$, $4\ R_1 = R_2$, **calculate** the ratio between the periodic time for each of them $\left(\frac{T_1}{T_2}\right)$.

Model Exam 9

First Choose the correct answer

1 The weight of an object on the Moon is 160 N, if the ratio between the gravitational field intensity on the Moon and that on Jupiter is 2 : 31, then the weight of the same object on Jupiter equals ....

(a) 10.3 N (b) 1240 N (c) 2480 N (d) 6200 N

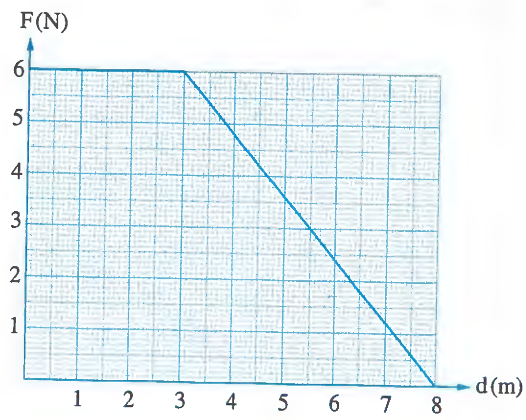
2 If the speed of an object is increased to double its value, then its kinetic energy becomes .... its value.

(a) quarter (b) half (c) double (d) four times

3 The opposite graph illustrates the relation between the force acting on a body and the displacement of the body due to this force, then the work done by this force equals ....

(a) 3 J (b) 33 J

(c) 48 J (d) 54 J



4 The speed of a satellite around a planet is 2×10^5 m/s and the radius of its orbit is 6.7×10^4 km, then the mass of the planet is ....

(a) 2.5×10^{18} kg (b) 2.5×10^{23} kg

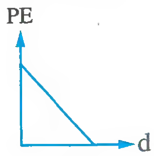
(c) 4.02×10^{20} kg (d) 4.02×10^{28} kg

5 A body has a mass of 40 kg on the Moon's surface, then its weight on the Earth's surface is ....

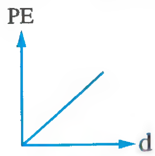
(knowing that : the acceleration due to gravity on Earth = 10 m/s^2)

(a) 400 N (b) 392 N (c) 66 N (d) 60 N

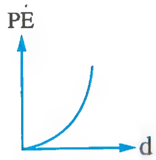
6. The best graphical representation for the potential energy (PE) of a free falling body as its height changes from its original position is ....



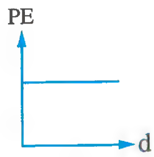
(a)



(b)



(c)



(d)

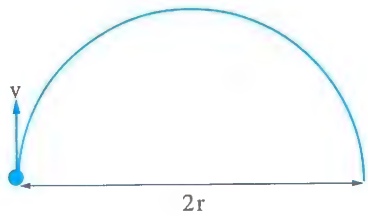
7. An object is moving in a circular path with a uniform speed, then the direction of its acceleration is ....

(a) in the direction of its velocity
(b) towards the center of rotation
(c) away from the center of rotation
(d) tangent to the circular path

8. An object falls freely so at the moment when its potential energy is less than its potential energy at the beginning of its falling by 100 J, its kinetic energy will be ....

(a) 50 J
(b) 100 J
(c) 200 J
(d) 400 J

9. The opposite figure illustrates an object moving in a curve in the form of half circle with a uniform speed, if it covers the curve within 8 s, then the tangential velocity of the object equals ....



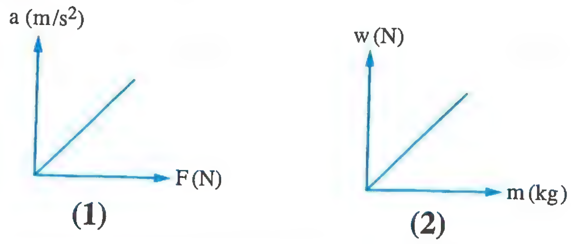
(a) $\frac{\pi r}{2}$
(b) $\frac{\pi r}{4}$
(c) $\frac{\pi r}{8}$
(d) $\frac{\pi r}{16}$

10. A metallic ball of mass 0.5 kg rotates in a horizontal circular path of radius 10 cm where it makes 150 revolutions every half a minute, so the centripetal force that acts on the ball equals .... N.

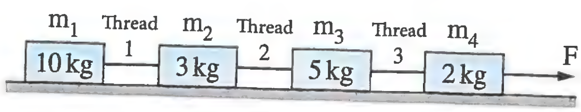
(a) 2π
(b) 5π
(c) $10\pi^2$
(d) $5\pi^2$

Second Answer the following questions

11 **Write the mathematical relation and the equivalent for the slope for each of the following graphs :**



12 The opposite figure shows four masses that are connected together by threads of negligible masses. If the masses are pulled by a horizontal force (F) on a frictionless smooth plane,



arrange ascendingly :

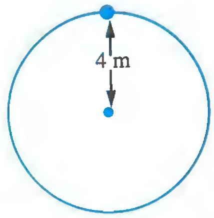
(1) The masses according to their accelerations.

(2) The threads according to the tension force in each of them.

13 According to Bohr's model for the atomic structure, the electron orbits the nucleus in a uniform circular orbit. **Explain why** the work done by the centripetal force on the electron equals zero during its rotation.

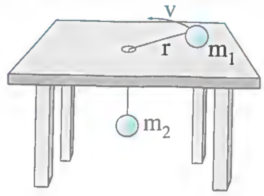
14 There is no collision between two satellites moving in the same orbit with the same speed. **Explain.**

15 The opposite figure shows a body of mass 1 kg that moves in a uniform circular path under the effect of a centripetal force of 100 N. **Calculate** the periodic time of the body's motion.



16 Two satellites are rotating around the Earth, if the first satellite rotates in an orbit of radius 4.23×10^7 m synchronized with the Earth and the second satellite rotates in another orbit of periodic time 12 hours, **calculate** the orbital velocity for the second satellite.

17 A wire passing through a hole in a table. A load of mass m_1 is attached at the end of the wire and moves in a uniform circular path of radius r with speed v and a load of mass m_2 is hanged from the other end of the wire as in figure.

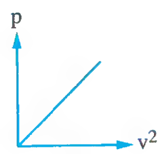


Find r in terms of m_1, m_2 and v neglecting the frictional forces.

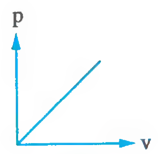
Model Exam 10

First Choose the correct answer

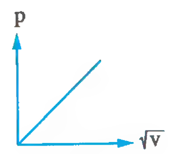
1 The graphical representation that represents the relation between the momentum and the velocity of a body is ....



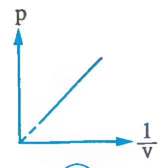
(a)



(b)



(c)

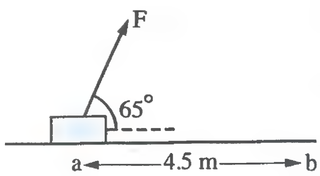


(d)

2 If the distance between two bodies and the mass of each of them were decreased to their half , then the attraction force between them ....

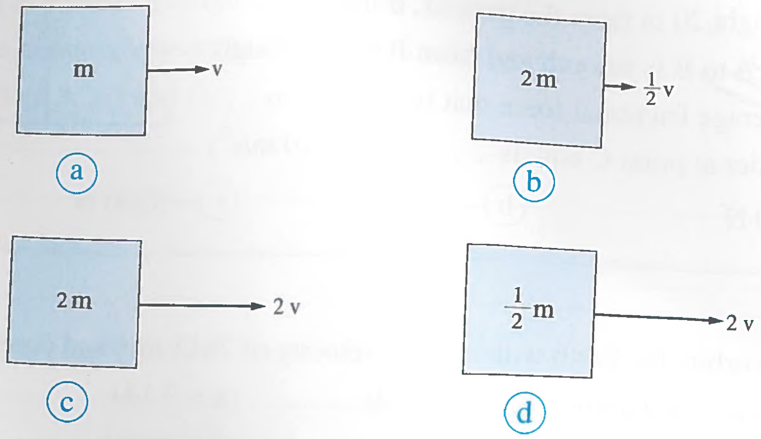
(a) decreases to its quarter
(b) increases 4 times
(c) remains constant
(d) decreases to its half

3 In the opposite figure :
A mass of 5 kg is placed on a smooth horizontal plane. A force of 40 N affects the mass and moves it from rest a distance of 4.5 m from point a to b, if the frictional force is 15 N, so ....



	The work done on the mass by the force to move it from a to b (J)	The velocity at b (m/s)
(a)	112.5	10.6
(b)	8.6	10.6
(c)	112.5	1.85
(d)	8.6	1.85

4 The following figures show four moving bodies that are different in mass, which of them has the largest kinetic energy ? ....



5 A satellite is orbiting the Earth where it is always above the same point with respect to the Earth's surface, if the height of the satellite is 36×10^3 km from the Earth's surface, then its orbital velocity is .... (R_e = 6378 km)

(a) 2.05×10^3 m/s
(b) 2.92×10^3 m/s
(c) 3.08×10^3 m/s
(d) 3.64×10^3 m/s

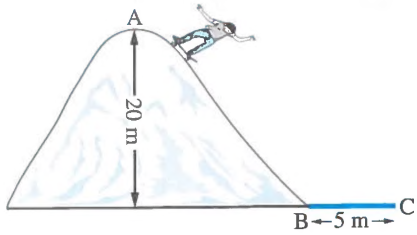
6 The work done on a body is negative when the force that acts on the body is .... direction of the displacement.

(a) in the same
(b) in the opposite
(c) perpendicular to the
(d) making an acute angle with the

7 Two bodies A and B of masses m and 2 m respectively are separated by a fixed distance, if body A pulls body B with a gravitational force that equals F, so body B pulls body A with a gravitational force that equals ....

(a) $\frac{F}{2}$
(b) F
(c) 2 F
(d) 4 F

8 The opposite figure shows the path of a skier of mass 80 kg. The skier slides from the top of a hill of height 20 m from the ground. If the path from point A to B is smooth and from B to C is rough , so the average frictional force that is required to stop the skier at point C equals .... ($g = 10\ m/s^2$)



(a) – 1600 N (b) – 2400 N (c) – 3200 N (d) – 4000 N

9 A satellite orbits the Earth with a linear velocity of 7613 m/s and completes one cycle in 94.4 minutes , so its orbital radius equals .... ($\pi = 3.14$)

(a) 4242 km (b) 5784 km (c) 6866 km (d) 7200 km

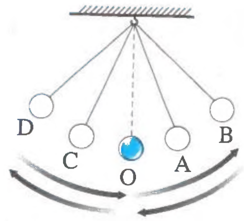
10 The gravitational force between two persons is F when the distance between them is d. If the distance between them becomes 3 d, then the force becomes ....

(a) 9 F (b) 3 F (c) $\frac{1}{3}$ F (d) $\frac{1}{9}$ F

Second Answer the following questions

11 A body of mass 1 kg rotates in a uniform circular path where it moves 10 m which represents 0.1 from its circular path in 1 s, **calculate** the centripetal force on the body.

12 The opposite figure shows a pendulum that has a mechanical energy of 10 J. The pendulum moves from point B to point D through the points A , O and C. **Calculate** the potential energy at B and the kinetic energy at each of A , O and D.

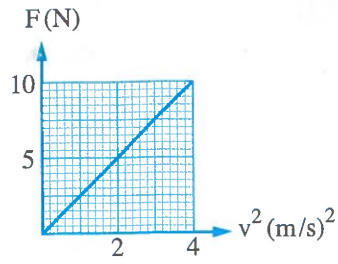


13 Suppose that the gravitational force of the Earth vanishes at a certain moment. **What will happen** to the satellites that orbit the Earth at that moment ? **Explain your answer.**

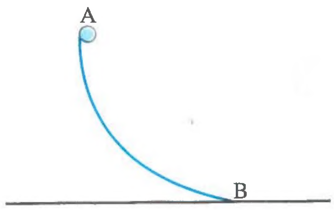
14 **Which point** on the surface of the Earth has the largest linear velocity with respect to the axis of the Earth, a point at the equator or a point at the tropics of Capricorn and Cancer ?

15 The opposite figure shows the relation between the centripetal force that affects a ball that is moving in a circular path of radius 0.4 m and the square of its linear velocity.

Calculate the mass of the ball.



16 A ball slides from rest on a frictionless track. **Compare between** each of potential energy, kinetic energy and mechanical energy of the ball at point A and B.



17 Two equal forces act on two bodies of masses 1 kg and 5 kg respectively where the second body accelerates by 20 m/s^2, **calculate** the acceleration of the first body.